The Electrochemical Society . . .

118th Meeting

Houston

Oct. 9, 10, 11, 12, and 13, 1960

LOCAL COMMITTEE

General Chairman
Oliver Osborn

Hotel Arrangements
John Loeffler

Registration
Ralph J. Hach

Finance
C. S. Templeton

Entertainment
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College Relations
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Membership
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Plant Trips
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Publicity
Frank Evans

Ladies' Program
Mrs. Emily Osborn

Houston Meeting

THE ELECTROCHEMICAL SOCIETY

One Hundred and Eighteenth Meeting

October 9, 10, 11, 12, and 13, 1960

Sunday through Thursday

CONDENSED TECHNICAL PROGRAM

Monday, Oct. 10, 1960

Battery (Abstracts 1-12) 9:30 A.M.-12:15 P.M.; 2:00-5:00 P.M. (Azalea Room, Exhibit Hall)
Corrosion (Abstracts 34-53) 9:00 A.M.-12:00 M.; 2:00-5:10 P.M. (Continental Room, Shamrock Hilton); 2:00-4:50 P.M. (El Shiro Room, Shamrock Hilton)
Electrodeposition—Electrothermics and Metallurgy (Abstracts 119-128) 9:30-11:40 A.M.; 2:00-4:10 P.M. (Grecian Room, Shamrock Hilton)
Electronics-Semiconductors (Abstracts 129-140) 9:15 A.M.-12:00 M.; 2:00-4:30 P.M. (Emerald Room, Shamrock Hilton)

Tuesday, Oct. 11, 1960

Battery (Abstracts 13-23) 9:00 A.M.-12:00 M.; 2:30-4:40 P.M. (Azalea Room, Exhibit Hall)
Corrosion (Abstracts 54-63) 9:00 A.M.-12:00 M.; 2:00-5:00 P.M. (Continental Room, Shamrock Hilton)
Electrodeposition (Abstracts 89-100) 9:00 A.M.-12:00 M.; 2:00-5:00 P.M. (Grecian Room, Shamrock Hilton)
Electronics-Semiconductors (Abstracts 141-157) 9:00 A.M.-12:00 M.; 2:00-5:05 P.M. (Emerald Room, Shamrock Hilton)
Electrothermics and Metallurgy (Abstracts 169-173) 9:30-11:40 A.M. (El Shiro Room, Shamrock Hilton)

Wednesday, Oct. 12, 1960

Battery (Abstracts 24-33) 9:00 A.M.-12:00 M.; 2:00-4:10 P.M. (Azalea Room, Exhibit Hall)
Corrosion (Abstracts 64-75) 9:00 A.M.-12:00 M.; 2:00-5:00 P.M. (Continental Room, Shamrock Hilton)
Electrodeposition (Abstracts 101-112) 9:00 A.M.-12:00 M.; 2:00-5:00 P.M. (Grecian Room, Shamrock Hilton)
Electronics-Semiconductors (Abstracts 158-168) 9:00-11:30 A.M.; 2:00-4:45 P.M. (Emerald Room, Shamrock Hilton)

Thursday, Oct. 13, 1960

Corrosion (Abstracts 76-85A) 9:00 A.M.-12:00 M.; 2:00-5:00 P.M. (Continental Room, Shamrock Hilton)
Electrodeposition (Abstracts 113-118) 9:00 A.M.-12:00 M. (Grecian Room, Shamrock Hilton)

GENERAL INFORMATION

Convention Headquarters is the Shamrock Hilton Hotel, Main at Holcombe Boulevard, Houston 1, Texas; Teletype No. 533, Telephone, Madison 3-9211.

Special rates per day secured only by PREREGISTRATION are: single rooms, $8.00, 10.00, 12.00, 14,00, 15.00; twin-bed rooms, $12.00, 14.00, 16.00, 18.00, 19.00; two rooms with connecting bath only on request. Suites, parlor with one bed room, $25.00, 30.00, 35.00, 40.00; parlor with twin-bed room, $55.00, 60.00, 65.00, 70.00.

Requests for room reservations should be mailed to the Shamrock Hilton Hotel, Main and Holcombe, Houston 1, Texas.

BE SURE to state that you will be attending The Electrochemical Society Meeting. If your wife will be attending, be sure to indicate this on your request for reservation.

The Office of the Secretary is in Room 337, Shamrock Hilton Hotel, 3rd floor, turn right.

The Local Committee Office and Press Headquarters on Sunday, Monday, and Tuesday, Oct. 9, 10, and 11, are adjacent to the Registration Area, Hall of Exhibits; on Wednesday and Thursday, Oct. 12 and 13, they are in the Walnut Room, 3rd floor, Shamrock Hilton.

REGISTRATION

The registration desk will be in the Hall of Exhibits directly connected to the Main Hotel Lobby on Sunday, Monday, and Tuesday, Oct. 9, 10, 11; on Wednesday and Thursday, Oct. 12 and 13, it will be located in the Venetian Room, 3rd floor, Shamrock Hilton, turn right.

The registration schedule is:

Hall of Exhibits

Sunday, October 9—12:00 M. to 9:00 P.M.
Monday, October 10—7:00 A.M. to 4:00 P.M.
Tuesday, October 11—8:00 A.M. to 4:00 P.M.

Venetian Room, 3rd floor, Shamrock Hilton

Wednesday, October 12—8:00 A.M. to 4:00 P.M.
Thursday, October 13—8:00 A.M. to 12:00 M.

Registration fees are:

Technical Session Registration (Men and Women)	
Member	$ 7.00
Nonmember Speakers and Coauthors	7.00
Nonmember	13.00*
Student Members	Complimentary
Student Nonmembers	2.00
Thursday Only	5.00
Ladies Registration Fee for Social Events	5.00

* If a nonmember fills out an application form and subsequently is elected to membership in the Society, the difference between the nonmember and member registration fee will be applied to his first year's dues.

INFORMATION ABOUT HOUSTON

Information about places of interest and other attractions will be available at the Local Committee Office adjacent to the Registration Area, Hall of Exhibits, Sunday through Tuesday, and in the Venetian Room, 3rd floor, Shamrock Hilton, Wednesday and Thursday, where a designated official will be

on hand to assist you, be it concerning airline schedules, restaurants, sight-seeing buses, theaters, etc.

SYMPOSIA

The Battery Division has scheduled a lead-acid storage battery symposium in honor of the 100th anniversary of the invention of the lead-acid battery by Gaston Plante, devoted to papers dealing with the processes involved in the corrosion of lead and the formation of active materials. The Division has also scheduled symposia on: Primary Cells; Solid Electrolyte, Secondary Battery Characteristics, and Silver/Silver Oxide Electrodes; and Nickel-Cadmium.

The Corrosion Division has scheduled symposia on: Can Corrosion; Oxidation; Unusual Valence States and the Difference Effect; Certain Properties of the Interface Related to Corrosion; Passivity; Dissolution of Metals and Semiconductors; and a General Session.

The Electrodeposition Division has scheduled symposia on: Electroless and Immersion Plating; Electrophoretic Deposition; Metal Deposition; Alloy Plating; and a General Session.

The Electrodeposition and **Electrothermics and Metallurgy Divisions** have scheduled a Joint Symposium on Vapor Deposited Coatings.

The Electronics Division-Semiconductor Group has scheduled symposia on: Crystal Growth; Compound Semiconductors; Technology; and Surfaces.

The Electrothermics and Metallurgy Division has scheduled a session on Vacuum-Evaporated Films; Refractory and Reactive Metals.

GENERAL FUNCTIONS

Symposia Chairmen Breakfasts

On Monday, Tuesday, Wednesday, and Thursday, Oct. 10, 11, 12, and 13, special breakfasts will be held for symposia chairmen. On the day on which he presides at a session, each chairman should be in the Castillian Room A, 3rd floor, Shamrock Hilton, **at 7:45 A.M.**

Sunday Deep Sea Fishing Trip

The party will leave Freeport, Texas (weather permitting) aboard safe chartered boats **very early** Sunday morning, Oct. 9, for a day of fishing 12 to 60 miles out in the Gulf, returning to the Freeport dock about 5 or 6 P.M. Red snapper, ling, and warsaw will be the probable catches. A grub stake, tackle, bait, and transportation to and from Houston are all part of the package.

Sunday Evening Mixer

There will be a Sunday Evening Social get-acquainted gathering in the Grecian Room just off the Hotel Lobby from 6:00 to 8:00 P.M. All those registered for The Electrochemical Society Meeting are invited to attend. Beer, soft drinks, and snacks will be served on a complimentary basis. Mixed drinks may be purchased at the bar. Admission is by registration badge.

Monday Cocktail Party and Texas Style Barbecue

Arrangements have been made with the Shamrock Hilton Hotel to provide a traditional Texas Barbecue on and around the Hotel's triangular adjoining lawns. Soft drinks and cocktails will be served at 5:00 P.M. The famous Texas local Sheriff's Mounted Posse and their horses will perform for the entertainment of the guests, this being the featured attraction of the evening. Be on the Shamrock Hilton triangular lawns promptly at 5:00 P.M., Oct. 10, for this event. Barbecue and other food will be served at 6:00 P.M. Tickets for this function will be available at the Society's registration desk. This event starts early to prevent the early fall darkness in this locale from interfering with your pleasure.

Tuesday Acheson Medal Reception and Banquet

A reception honoring Dr. Henry B. Linford, the Acheson Medalist, will be held at 6:30 P.M. on Tuesday, Oct. 11, in the Grecian Room, Shamrock Hilton Hotel, just off the Lobby Promenade. Cocktails and soft drinks will be served from 6:30 to 7:30 P.M. The banquet, in the connecting Emerald Room, will begin at 7:30 P.M. Dr. Linford will deliver the Acheson Medal address.

Wednesday Student Round Table and Reception

On Wednesday, Oct. 12, at 3:00 P.M. in the Normandy Room, 3rd floor, Shamrock Hilton, representatives of the various divisions of the Society will discuss the nature of technical activities of interest to each division for specially invited students (seniors and early graduates) and their sponsoring professors from colleges and universities in the Houston area. The object of this function, sponsored by the Society, is to inform students of the opportunities and future in electrochemistry. Following the round-table discussion, a reception and mixer for this group will be held in the Castillian Room, 3rd floor, at 5:00 P.M. Refreshments will be served on a complimentary basis.

PLANT TRIPS

Tuesday—Diamond Alkali Corp.

A tour of the Houston Ship Channel and the Deer Park Plant of the Diamond Alkali Corporation has been arranged. Buses will depart promptly from the main entrance of the Shamrock Hilton Hotel at 1:30 P.M. on Tuesday, Oct. 11, and proceed to the Houston Channel Turning Basin where the party will board the Navigation District's Inspection Boat "Sam Houston." The boat will proceed down the channel for about 15 miles, passing many chemical plant sites. The group will leave the boat at the Diamond Alkali Plant for an inspection of their diaphragm and mercury cell chlorine facilities and utility department. At the completion of the tour, buses will return to the hotel, about 5:45 P.M. The cost per person for the tour is $2.50. The boat trip is provided through the courtesy of the Port of Houston. Attendance will be limited to 50.

Wednesday—Dow Chemical Co.

Buses will depart at 1:30 P.M. on Wednesday, Oct. 12, for a tour of The Dow Chemical Company magnesium reduction plant at Freeport, Texas. This will include a general tour of

the chemical plant and an inspection of the operating magnesium cells. Following the tour, a barbecue dinner will be served courtesy of The Dow Chemical Company at the Company Park. Buses will return to the Hotel by 8:00 P.M. Attendance will be limited.

LADIES' PROGRAM

All the ladies are invited to make the Nile Room (turn right on 3rd floor from the elevators), Shamrock Hilton, their headquarters during their stay in Houston. Members of the Ladies' Committee will be there to give information and assist in making your stay a pleasant one. Due to the isolated nature of the Shamrock Hilton Hotel our functions will be mainly in the morning to allow freedom in the afternoon either to relax by the magnificent Shamrock Hilton pool or to make shopping trips to downtown Houston. The Nile Room will be our Hospitality Headquarters.

Sunday, Oct. 9—Start out on the right social foot. Attend the Sunday Evening Mixer in the Grecian Room (take right Promenade, then turn left) from 6:00 to 8:00 P.M. Admission by registration badge.

Monday, Oct. 10—Coffee hour at 9:30 A.M. The ladies are free for the day but are urged to attend the Cocktail Party, Barbecue, and typical Texas-type entertainment of the Sheriff's Mounted Posse that evening at 5:00 P.M. on the front lawn of the hotel.

Tuesday, Oct. 11—Continental breakfast at 9:30 A.M., followed by a talk and demonstration by Mrs. Veberly Nixon, Adult Homemaking teacher for the Brazosport Schools, entitled "Millinery Made at Home" at 10:30 A.M. The ladies are invited to attend the Acheson Medal Reception and Banquet that evening at 6:30 P.M.

Wednesday, Oct. 12—Coffee hour at 9:30 A.M. followed by a sightseeing trip by air-conditioned bus, with a hostess to describe the Rice Institute Campus, the world-known Texas Medical Center, etc., and then on to the Gulfgate Shopping Center for souvenir and other shopping; the trip starts at 10:00 A.M. and return should be about 3:00 P.M.

Thursday, Oct. 13—Coffee hour at 9:30 A.M. followed by a talk at 11:00 A.M. by Mrs. Betty Smith of the John Robert Powers modeling school. If you can stay through luncheon, there will be the regular Thursday Styles Show and Luncheon in the Emerald Room at 12:30 P.M.

BOARD AND COMMITTEE MEETINGS

Sunday, Oct. 9, 2:00 P.M.—Meeting of the **Board of Directors,** Castillian Room B and C, 3rd floor, Shamrock Hilton.

Monday, Oct. 10, 2:00 P.M.—Meeting of the **Convention Advisory Committee,** Room 335, Shamrock Hilton.

Monday, Oct. 10, 12:15 P.M.—Luncheon Meeting of the **Membership Committee,** Castillian Room B and C, 3rd floor, Shamrock Hilton.

Tuesday, Oct. 11, 5:00 P.M.—Meeting of the **Editorial Staff of the Journal,** Castillian Room B and C, 3rd floor, Shamrock Hilton.

Tuesday, Oct. 11, 5:00 P.M.—Meeting of the **Council of Local Sections,** Normandy Room, 3rd floor, Shamrock Hilton.

Wednesday, Oct. 12, 12:00 M.—Luncheon meeting of the **General Chairmen of Future Meetings** in Castillian Room A, 3rd floor, Shamrock Hilton, at 12:00 M.

LUNCHEONS AND BUSINESS MEETINGS OF DIVISIONS

Battery Division Luncheon and Business Meeting, **Tuesday,** Oct. 11, 12:30 P.M., on the Terrace, Shamrock Hilton.

Electronics Division, Semiconductor Group Luncheon, **Tuesday,** Oct. 11, 12:30 P.M., in the Castillian Room, 3rd floor, Shamrock Hilton.

1961 SPRING MEETING
at the
Claypool Hotel
INDIANAPOLIS, INDIANA
April 30, May 1, 2, 3, and 4, 1961

Sessions probably will be scheduled on:
Electric Insulation
Electronics (including Luminescence and Semiconductors)
Electrothermics and Metallurgy
Industrial Electrolytics
Theoretical Electrochemistry

Abstracts for the Indianapolis Meeting (*not exceeding 75 words in length*) must reach Society Headquarters, 1860 Broadway, New York 23, N. Y., *not later than* January 2, 1961 to be included in the Program.

Please *indicate* on the abstract *for which Division's symposium the paper is to be scheduled* and *underline the name of the author who will present the paper* at the Indianapolis Meeting.

Presentation of a paper at a technical meeting of the Society does not guarantee publication in the JOURNAL. However, all papers so presented become the property of The Electrochemical Society, and may not be published elsewhere, either in whole or in part, unless permission for release is requested of and granted by the Editor. Papers already published elsewhere, or submitted for publication elsewhere, are not acceptable for oral presentation except on invitation by a Divisional program Chairman.

Corrosion Division Luncheon and Business Meeting, **Wednesday,** Oct. 12, 12:30 P.M., in the Castillian Room, 3rd floor, Shamrock Hilton.

Electrodeposition Division Luncheon and Business Meeting, **Wednesday,** Oct. 12, 12:30 P.M., on the Terrace, Shamrock Hilton.

COST OF VARIOUS FUNCTIONS

(other than registration)

Please buy tickets at time of registration, if possible.

Deep Sea Fishing Trip	$25.00
Symposia Chairmen Breakfasts	Menu prices
Sunday Evening Mixer	Complimentary
Monday Cocktail Party and Barbecue	7.50
Tuesday Plant Trip to Diamond Alkali Corp.	2.50
Tuesday Acheson Medal Reception and Banquet	8.00
Division Luncheons	3.50
Wednesday Ladies' Shopping Tour	1.00
Wednesday Plant Trip to Dow Chemical Co.	2.50

JOURNALS

Copies of the June, July, August, and September issues of the "Journal of The Electrochemical Society" will be available at the Registration Desk on Sunday, Monday, and Tuesday in the Hall of Exhibits' entrance, and on Wednesday and Thursday in the Venetian Room, 3rd floor, Shamrock Hilton. The price of a single copy of the **Journal** is $1.25 to members and $1.75 to nonmembers.

EXTENDED ABSTRACTS

The Battery Division is making available an extended abstract booklet containing 1000-word abstracts of most of the papers presented at the Division's Houston Meeting. Copies of the booklet may be obtained from C. H. Clark, 34 Pleasant Way, Deal, N. J., after Sept. 15 for $2.00 each.

EMPLOYMENT POSTERS

Companies which desire to recruit employees at the Houston Meeting will have posters to this effect on a Bulletin Board adjacent to the Registration Desks (see Registration for location). Companies are requested to confine their announcements to this Bulletin Board.

DISCUSSION

No recordings will be made of oral discussion. Those contributing to the discussion of a paper and desiring their remarks to be published will be supplied by the symposium chairman with a printed form on which any discussion may be written. These forms should be given to the symposium chairman or to the Managing Editor of the **Journal** after the session; or they can be mailed to the Managing Editor of the **Journal,** 1860 Broadway, New York 23, N. Y. The discussion will then be referred to the author for reply. Publication of the discussion and the comments of the author depends on publication of the article in the **Journal.**

Written discussion of a published paper should be submitted within two months following publication of the article in the **Journal.** A Discussion Section is published semiannually in the **Journal.**

MEETING ROOM SCHEDULE

Meeting	Monday		Tuesday		Wednesday		Thursday	
	AM	PM	AM	PM	AM	PM	AM	PM
Battery	E	E	E	E	E	E		
Corrosion	B	BD	B	B	B	B	B	B
Electrodeposition			C	C	C	C	C	
Electrodeposition—Electrothermics and Metallurgy	C	C						
Electronics—Semiconductor	A	A	A	A	A	A		
Electrothermics and Metallurgy			D					

Shamrock Hilton
A = Emerald Room, Lobby floor.
B = Continental Room, Lobby floor.
C = Grecian Room, Lobby floor.
D = El Shiro Room.

Exhibit Hall
E = Azalea Room.

NOTE

Photographing of lantern slides, charts, etc., will be permitted unless specifically prohibited by the speaker. Photo flash and photo floods are prohibited.

Technical Program—Houston Meeting

MONDAY, A.M., Oct. 10, 1960

BATTERY

G. W. Vinal, Honorary Chairman. Primary Cells with W. S. Herbert presiding

(AZALEA ROOM, Exhibit Hall, entrance on Holcombe Blvd.)

9:30 A.M.—"Ambient Temperature Fuel Cells" by H. F. Hunger (Abstract No. 1)

10:00 A.M.—"Electrode Kinetics of Various Redox Couples for Fuel Cell Use" by A. P. Bond and D. Singman (Abstract No. 2)

10:30 A.M.—"Investigation of the Electrochemical Characteristics of Organic Compounds, VIII. Hydrazine and Hydroxylamine Compounds" by R. Glicksman (Abstract No. 3)

11:00 A.M.—"Factors Affecting the Discharge Characteristics of Thermal Cells" by C. W. Jennings (Abstract No. 4)

11:25 A.M.—"Recent Studies on Ammonia Battery Systems" by Otto Adlhart and H. R. Knapp (Abstract No. 5)

11:50 A.M.—"The Photogalvanic Effect in Inorganic Oxidation-Reduction Systems, I. The Iodine-Iodide System" by H. N. Seiger and R. A. Marcus (Abstract No. 6)

CORROSION

Can Corrosion, with E. L. Koehler presiding

(CONTINENTAL ROOM, Shamrock Hilton, off Main Lobby)

9:00 A.M.—"A Hypothesis for the Uncoupling Shift Observed in the Iron-Tin System in Citric Acid" by W. R. Buck, III, A. N. J. Heyn, and Henry Leidheiser, Jr. (Abstract No. 34)

9:30 A.M.—"Effect of Tin Ion Complexing Substances on the Relative Potentials of Tin and Steel in Oxygen Free Acid Media" by A. R. Willey (Abstract No. 35)

10:00 A.M.—"Oxide Films on Tin Plate" by M. Falkenhagen and J. D. Bode (Abstract No. 36)

10:25 A.M.—Ten-minute intermission

10:35 A.M.—"Some Factors Affecting the Surface Chromium Content of Electrochemically Treated Tin Plate" by P. R. Carter (Abstract No. 37)

11:00 A.M.—"Use of Polarization Methods in the Determination of the Rate of Corrosion of 3003 Aluminum in Anaerobic Acid Media" by S. Evans and E. L. Koehler (Abstract No. 38)

11:30 A.M.—"Use of Polarization Methods in the Determination of the Rate of Corrosion of Aluminum Alloys in Anaerobic Food Media" by E. L. Koehler and S. Evans (Abstract No. 39)

ELECTRODEPOSITION and ELECTROTHERMICS AND METALLURGY

Joint Symposium on Vapor Deposited Coatings, with J. M. Blocher, Jr. presiding

(GRECIAN ROOM, Shamrock Hilton, take right Promenade, then turn left)

9:30 A.M.—"Prepurification Techniques: Their Role in Metal Production" by R. G. Bourdeau and E. Rose (Abstract No. 119)

9:55 A.M.—"Mass and Heat Transfer during the Vapor Deposition of Metals" by J. H. Oxley and J. M. Blocher, Jr. (Abstract No. 120)

10:20 A.M.—"Mechanism of Hydrogen Reduction of Cuprous Iodide Vapor" by C. R. Morelock and G. W. Sears (Abstract No. 121)

10:50 A.M.—"Tungsten Coatings by Gas Phase Deposition" by W. E. Reid, Jr., and Abner Brenner (Abstract No. 122)

11:15 A.M.—"Fluidized-Bed Coating of Uranium Dioxide Powder Particles with Niobium and Other Elements" by J. M. Blocher, Jr., N. D. Veigel, J. H. Oxley, V. M. Secrest, and E. E. Rose (Abstract No. 123)

ELECTRONICS—SEMICONDUCTORS

Crystal Growth, with H. E. Bridgers presiding

(EMERALD ROOM, Shamrock Hilton, off main Lobby)

9:15 A.M.—"Growth Steps on the Surfaces of Germanium, Silicon, and III-V Compound Dendrites" by G. R. Booker (Abstract No. 129)

9:40 A.M.—"Silicon Dendrite Studies" by S. N. Dermatis and J. W. Faust, Jr. (Abstract No. 130)

10:00 A.M.—"Investigations of Crystal Perfection of Semiconductor Crystals by X-Ray Diffraction Microscopy" by G. H. Schwuttke (Abstract No. 131)

10:20 A.M.—"Germanium Structural Defects—Their Cause and Effect" by D. H. Lyon (Abstract No. 132)

10:45 A.M.—"Horizontal Growth of Germanium Single Crystals Using a Silicon Nitride Receptacle" by J. L. Porter (Abstract No. 133)

11:05 A.M.—"Simple Method of Determining Crystal Perfection, II" by H. K. Herglotz (Abstract No. 134)

11:25 A.M.—Recent News Papers. Titles and short abstracts will be available at the Registration Desk.

MONDAY P.M., Oct. 10, 1960

BATTERY (Cont'd)

Primary Cells with C. H. Clark presiding

(AZALEA ROOM, Exhibit Hall, entrance on Holcombe Blvd.)

2:00 P.M.—"Investigation of the Electrochemical Characteristics of Organic Compounds, VII. Organic Positive Iodine and Aliphatic Azo Compounds" by R. Glicksman and C. K. Morehouse (Abstract No. 7)

2:30 P.M.—"Stability and Solubility of Silver Oxide Electrodes in Alkaline Electrolytes" by R. F. Amlie and Paul Ruetschi (Abstract No. 8)

3:00 P.M.—"The Magnesium-m-Ditnitrobenzene Cell" by G. S. Lozier, R. Glicksman, and J. B. Eisen (Abstract No. 9)
3:30 P.M.—"The Influence of the Active Surface on the Cathodic Reduction of MnO_2" by N. C. Cahoon and M. P. Korver (Abstract No. 10)
4:00 P.M.—"Impedance of Dry Cells and Batteries" by R. J. Brodd (Abstract No. 11)
4:30 P.M.—"Recharging of Leclanche Dry Cells" by W. S. Herbert (Abstract No. 12)

CORROSION (Cont'd)

Oxidation, with A. Dravnieks presiding

(CONTINENTAL ROOM, Shamrock Hilton, off Main Lobby)

2:00 P.M.—"The Oxidation of Tin, II. Morphology and Mode of Growth of Oxide Films on Pure Tin" by W. E. Boggs, P. S. Trozzo, and G. E. Pellissier (Abstract No. 40)
2:25 P.M.—"The Oxidation of Tin, I. Kinetics of Oxidation of Pure Tin and the Effects of Temperature and Oxygen Pressure" by W. E. Boggs, R. H. Kachik, and G. E. Pellissier (Abstract No. 41)
2:40 P.M.—"The Oxidation of Tin, III. Mechanisms of Oxidation of Pure Tin" by W. E. Boggs (Abstract No. 42)
2:55 P.M.—"Microtopography of Oxide Films Formed on Tantalum" by R. E. Pawel, J. V. Cathcart, and J. J. Campbell (Abstract No. 43)
3:20 P.M.—Ten-minute intermission
3:30 P.M.—"Interaction between Copper and Gas Discharge Products Condensed at Very Low Temperatures" by Jerome Kruger and W. J. Ambs (Abstract No. 44)
3:55 P.M.—"Copper Oxides on the Surface of Gold Plate" by M. S. Frant and R. Rajaraman (Abstract No. 45)
4:20 P.M.—"Oxidation of Copper between 250° and 450°C and the Growth of CuO 'Whiskers' " by E. A. Gulbransen, T. P. Copan, and K. F. Andrew (Abstract No. 46)
4:45 P.M.—"Corrosion Rate of Fe in High-Temperature H_2O by an Electrical Resistance Method" by A. J. Panson (Abstract No. 47)

CORROSION (Cont'd)

Unusual Valence States and the Difference Effect, with R. T. Foley presiding

(EL SHIRO ROOM, Shamrock Hilton, take right Promenade, then turn left)

2:00 P.M.—"Unusual Oxidation States Encountered in Corrosion Processes" by E. C. Pitzer (Abstract No. 47A)
2:20 P.M.—"Evidence for One-Electron Oxidation as Primary Electrode Reaction in Anodic Dissolution of Bivalent Metals" by A. W. Davidson (Abstract No. 48)
2:50 P.M.—"The Relative Stabilities of Oxidation States of Transitional Metals" by G. W. Watt (Abstract No. 49)
3:20 P.M.—Ten-minute intermission
3:30 P.M.—"Valency of Ions Formed during Anodic Dissolution of Metals in Acids" by M. E. Straumanis (Abstract No. 50)

4:00 P.M.—"The Difference Effect and Anodic Behavior of Zirconium Dissolving in Hydrofluoric Acid" by M. E. Straumanis, W. J. James, and W. C. Custead (Abstract No. 51)
4:30 P.M.—"The Difference Effect and the Chunk Effect" by G. A. Marsh and E. Schaschl (Abstract No. 52)

ELECTRODEPOSITION and ELECTROTHERMICS AND METALLURGY (Cont'd)

Joint Symposium on Vapor Deposited Coatings (cont'd) with J. M. Blocher, Jr., presiding

(GRECIAN ROOM, Shamrock Hilton, take right Promenade, then turn left)

2:00 P.M.—"Vapor Deposition of Carbon onto Sintered UO_2 Reactor Fuel" by E. G. Wintucky and E. H. Layer (Abstract No. 124)
2:25 P.M.—"Oxidation Resistant Silicide Coatings for Columbium and Tantalum Alloys" by R. Lorenz and A. B. Michael (Abstract No. 125)
2:50 P.M.—"Diffusion Coatings of Refractory Metals on Steel" by R. E. Bessey and W. M. Kisner (Abstract No. 126)
3:15 P.M.—"Industrial Aspects of Vapor-Deposited Coatings" by H. W. Schultze (Abstract No. 127)
3:45 P.M.—"Testing of Vapor-Plated Aluminum Films" by F. V. Schossberger and K. D. Franson (Abstract No. 128)

ELECTRONICS—SEMICONDUCTORS (Cont'd)

Compound Semiconductors, with W. J. Turner presiding

(EMERALD ROOM, Shamrock Hilton, off main Lobby)

2:00 P.M.—"Synthesis and Crystal Pulling of Gallium Arsenide in a Magnetic Crystal Puller" by K. Weiser and S. Blum (Abstract No. 135)
2:20 P.M.—"Graded Energy Gap Alloy Semiconductor—$GaAs_xP_{1-x}$" by R. E. Johnson and George Towns (Abstract No. 136)
2:40 P.M.—"Preparation of Gallium Phosphide under Moderate Pressures of Phosphorus Vapor" by J. F. Miller, R. C. Himes, and H. L. Goering (Abstract No. 137)
3:00 P.M.—"Direct Recombination in GaAs" by S. Mayburg (Abstract No. 138)
3:20 P.M.—"Reactions between Gallium and Quartz" by L. M. Foster and R. A. Kramer (Abstract No. 139)
3:40 P.M.—"Analysis of Impurities in Compound Semiconductors" by G. D. Perkins, C. F. Robinson, and R. K. Willardson (Abstract No. 140)
4:00 P.M.—Recent News Papers. Titles and Short Abstracts will be available at the registration desk.

TUESDAY A.M., Oct. 11, 1960

BATTERY (Cont'd)

Lead-Acid Storage Batteries. 100th Anniversary Plante Session, with E. J. Ritchie presiding

(AZALEA ROOM, Exhibit Hall, entrance on Holcombe Blvd.)

9:00 A.M.—Introductory remarks by G. W. Vinal.

9:10 A.M.—"Is the Lead-Acid Battery Obsolete?" by Paul Ruetschi (Abstract No. 13)
10:00 A.M.—"How Lead Becomes a Battery" by R. Jardine and S. K. Lessey (Abstract No. 14)
10:40 A.M.—"The Anodic Oxidation Rate of Pure Lead in Sulfuric Acid" by R. A. Baker (Abstract No. 15)
11:00 A.M.—"Plante, Pourbaix, and Passivation" by Jeanne Burbank (Abstract No. 16)
11:30 A.M.—"Mechanisms of the Electrode Reactions in Lead Accumulators" by W. F. K. Wynne-Jones (Abstract No. 17)
12:30 P.M.—Battery Division Luncheon and Business Meeting, Terrace, Shamrock Hilton.

CORROSION (Cont'd)

Certain Properties of the Interface Related to Corrosion, with G. H. Cartledge presiding

(CONTINENTAL ROOM, Shamrock Hilton, off main Lobby)

9:00 A.M.—"Adsorption and Ion Exchange at the Corrosion Interface" by G. H. Cartledge (Abstract No. 54)
9:30 A.M.—"Proton Mobility in Liquids and Solids" by B. E. Conway (Abstract No. 55)
10:00 A.M.—"The Structure of the Corroding Interface" by T. P. Copan (Abstract No. 56)
10:30 A.M.—Fifteen-minute intermission
10:45 A.M.—"Effects of Corrosion Films on Cathodic Processes" by R. E. Meyer (Abstract No. 57)
11:15 A.M.—Discussion period. Discussion initiated by Norman Hackerman

ELECTRODEPOSITION

Electroless and Immersion Plating, with Abner Brenner presiding

(GRECIAN ROOM, Shamrock Hilton, take right Promenade, then turn left)

9:00 A.M.—"Chemical Deposition of Palladium and Other Platinum Metals" by R. N. Rhoda (Abstract No. 89)
9:30 A.M.—" 'Electroless' Deposition of Gold from Aqueous Solution on Base Metals of Nickel, Iron-Nickel-Cobalt Alloys and Gold" by R. F. Walton (Abstract No. 90)
10:00 A.M.—"Chemical Plating with Borohydrides" by E. A. Sullivan (Abstract No. 91)
10:30 A.M.—"An Electroless Copper Plating System for 'Pure' Aluminum" by S. L. Matlow (Abstract No. 92)
11:00 A.M.—"Mechanisms of Electroless Deposition of Metals on Silicon" by S. L. Matlow (Abstract No. 93)
11:30 A.M.—"Immersion Coatings of the Platinum Metals" by R. W. Johnson (Abstract No. 94)

ELECTRONICS—SEMICONDUCTORS (Cont'd)

Compound Semiconductors (Cont'd) with R. Sangster presiding

(EMERALD ROOM, Shamrock Hilton, off main Lobby)

9:00 A.M.—"Some Comments on the Electronic Structure of Group IV and III-V Semiconductors" by S. L. Matlow (Abstract No. 141)

9:20 A.M.—"Physical Properties of p-Type Zn_3As_2 and n-Type Cd_3As_2" by W. J. Turner, A. S. Fischler, and W. E. Reese (Abstract No. 142)
9:40 A.M.—"Mobility Doping of Semiconducting Compounds" by A. J. Cornish (Abstract No. 143)
10:00 A.M.—"Thermoelectric and Crystallographic Properties of Ag_2Se" by J. B. Conn and R. C. Taylor (Abstract No. 144)
10:20 A.M.—"Properties of HgSe-HgTe Alloys" by T. C. Harman, A. J. Strauss, and L. B. Farrell (Abstract No. 145)
10:40 A.M.—"Crystal Orientation Effects Observed in Tin-Telluride Thin Films" by S. H. Shortes and D. P. Miller (Abstract No. 146)
11:00 A.M.—"The Growth of Single Crystal Iron Ferrites by the Czochralski Method" by F. H. Horn (Abstract No. 147)
11:20 A.M.—"Titanium Thin Film Resistance for Microsystems Electronics" by R. A. Quinn (Abstract No. 148)
11:40 A.M.—Recent News Papers. Titles and Short Abstracts will be available at the Registration Desk.
12:30 P.M.—Electronics—Semiconductor Luncheon, Castillian Room, 3rd floor, Shamrock Hilton.

ELECTROTHERMICS AND METALLURGY

Vacuum-Evaporated Films; Refractory and Reactive Metals, with E. M. Sherwood presiding

(EL SHIRO ROOM, Shamrock Hilton, take right Promenade, then turn left)

9:30 A.M.—"Vacuum-Evaporated Titanium Coatings" by C. Horn and D. K. Wilburn (Abstract No. 169)
9:55 A.M.—"Deposition of InSb Films by Flash Evaporation" by E. H. Layer, F. J. Reid, and A. E. Austin (Abstract No. 170)
10:20 A.M.—"Vacuum Sintering of Tungsten Ingots" by J. W. Pugh and L. H. Amra (Abstract No. 171)
10:45 A.M.—Five-minute intermission
10:50 A.M.—"Reactions in the Niobium-Nitrogen System" by W. M. Albrecht and W. D. Goode (Abstract No. 172)
11:15 A.M.—"Preparation of Rare Earth Master Alloys" by S. J. Morana (Abstract No. 173)

TUESDAY P.M., Oct. 11, 1960

BATTERY (Cont'd)

Lead-Acid Storage Batteries. 100th Anniversary Plante Session (Cont'd), with W. J. Hamer presiding

(AZALEA ROOM, Exhibit Hall, entrance on Holcombe Blvd.)

2:30 P.M.—"Formation Studies of Lead-Acid Battery Plates Using the Electron Microscope" by J. E. Buskirk, P. D. Boyd, and V. V. Smith (Abstract No. 19)
2:55 P.M.—"Electrode Potentials and Thermal Decomposition of α- and β-PbO_2" by R. T. Angstadt and Paul Ruetschi (Abstract No. 20)
3:20 P.M.—"Some Important Factors That Influence the Composition of Positive Plate Material" by V. H. Dodson (Abstract No. 21)

3:50 P.M.—"Composition and Performance of Positive Plate Material" by V. H. Dodson (Abstract No. 22)

4:15 P.M.—"The Next Hundred Years" by E. Willihnganz (Abstract No. 23)

CORROSION (Cont'd)

General Session, with M. A. Streicher presiding

(CONTINENTAL ROOM, Shamrock Hilton, off main Lobby)

2:00 P.M.—"Dissolution of Mild Steel in the System NH_4NO_3-NH_3-H_2O at 30°C" by J. D. Goodrich and Norman Hackerman (Abstract No. 58)

2:30 P.M.—"Corrosion Inhibition and Electronic Configuration at the Amino Nitrogen Atom" by Norman Hackerman, R. R. Annand, and R. M. Hurd (Abstract No. 59)

3:00 P.M.—"Capacitance Studies on Corroding Metal Electrodes" by H. M. Joseph and R. A. Powers (Abstract No. 60)

3:25 P.M.—Ten-minute intermission

3:35 P.M.—"Hydrogen Pickup in Various Zirconium Alloys during Corrosion Exposure in High-Temperature Water and Steam" by Stanley Kass (Abstract No. 61)

4:00 P.M.—"Kinetics of Sulfidization of Copper by Hydrogen Sulfide" by Andrew Dravnieks (Abstract No. 62)

4:30 P.M.—"Copper Sulfide Creep on Porous Electroplate" by M. S. Frant (Abstract No. 63)

ELECTRODEPOSITION (Cont'd)

Electrophoretic Deposition, with A. H. Beebe presiding

(GRECIAN ROOM, Shamrock Hilton, take right Promenade, then turn left)

2:00 P.M.—"Impedance Phenomena in Molten Salts" by G. J. Hills and K. E. Johnson (Abstract No. 95)

2:30 P.M.—"Electrolytic Metallide Coatings in Molten Fluoride" by N. C. Cook (Abstract No. 96)

3:00 P.M.—"Electrophoretic Deposition of Oxidation-Resistant Coatings on Molybdenum and Solid Lubricant Coatings on 304 Stainless Steel" by P. F. Campbell, K. A. Gebler, and S. J. Klack (Abstract No. 97)

3:30 P.M.—"Electrophoretic Deposition: A Versatile Coating Method" by C. P. Gutierrez, J. R. Mosley, and T. C. Wallace (Abstract No. 98)

4:00 P.M.—"Electrophoretic Deposition of Aluminum" by F. Pearlstein, R. Wick, and A. Gallaccio (Abstract No. 99)

4:30 P.M.—"The Electrodeposition of Cermets" by J. C. Withers (Abstract No. 100)

ELECTRONICS—SEMICONDUCTORS (Cont'd)

Technology, with F. Biondi presiding

(EMERALD ROOM, Shamrock Hilton, off main Lobby)

2:00 P.M.—"Some Statistics of Doping Silicon Crystals" by J. W. Brownson and R. Saphir (Abstract No. 149)

2:20 P.M.—"Method of Evaluating Silicon Monocrystals for the Fabrication of Diffused Junction Devices" by A. Ertel (Abstract No. 150)

2:45 P.M.—"A Modified Closed Box System for the Diffusion of Boron in Silicon" by R. S. Yatsko and J. S. Kesperis (Abstract No. 151)
3:05 P.M.—"Some Effects of Paint Strength Variation in Paint-on Diffusion of Silicon" by J. E. Reynolds and W. Gegg (Abstract No. 152)
3:20 P.M.—"Etching Ge with 'Superoxol' " by J. Bloem and J. C. van Vessem (Abstract No. 153)
3:40 P.M.—"Dissolution of Germanium in Hydrogen Peroxide" by Pei Wang and Nino Cerniglia (Abstract No. 154)
4:00 P.M.—"Sizing of Semiconductor Dice by Controlled Chemical Etching" by R. B. Soper (Abstract No. 155)
4:20 P.M.—"A New Technique for the Preparation of Flat Germanium Surfaces" by M. V. Sullivan and R. M. Finne (Abstract No. 156)
4:45 P.M.—"The Wetting of Germanium by Molten Indium" by A. A. Bergh and L. H. Holschwandner (Abstract No. 157)

WEDNESDAY A.M., Oct. 12, 1960

BATTERY (Cont'd)

Solid Electrolyte, Secondary Battery Characteristics, and Silver/Silver Oxide Electrodes, with U. B. Thomas presiding
(AZALEA ROOM, Exhibit Hall, entrance on Holcombe Blvd.)

9:00 A.M.—"Ionic Conductivity of Silver Iodide Pellets for Solid Electrolyte Batteries" by L. N. Mrgudich (Abstract No. 24)
9:30 A.M.—"The Ag/AgCl/ICl Solid Electrolyte Cell System" by D. M. Smyth and C. H. Tompkins (Abstract No. 25)
10:00 A.M.—"An Analytical Representation of the Characteristics of Commercial Secondary Batteries" by S. M. Selis and C. R. Russell (Abstract No. 26)
10:30 A.M.—"Float Characteristics of the Lead-Calcium Cell" by Jeanne Burbank and C. P. Wales (Abstract No. 27)
11:00 A.M.—"The Silver-Silver Oxide Electrode, I. Anodic Oxidation in Alkaline Solutions" by C. P. Wales (Abstract No. 28)
11:30 A.M.—"Electrode Phenomena of the Silver-Silver Oxide System in the Alkaline Battery" by Shiro Yoshizawa and Zenichiro Takehara (Abstract No. 29)

CORROSION (Cont'd)

Passivity, with Norman Hackerman presiding
(CONTINENTAL ROOM, Shamrock Hilton, off Main Lobby)

9:00 A.M.—"Anode Polarization Effects" by O. L. Riggs, Jr., J. D. Sudbury, and D. A. Shock (Abstract No. 64)
9:30 A.M.—"Anodic Behavior of Austenitic Stainless Steels and Susceptibility to Stress Corrosion Cracking" by S. Barnartt and D. van Rooyen (Abstract No. 65)
10:00 A.M.—"The Volatilization of Chromium Oxide" by D. Caplan and M. Cohen (Abstract No. 66)
10:25 A.M.—Ten-minute intermission
10:35 A.M.—"The Passivity of Austenitic Stainless Steels in Sulfuric Acid" by N. D. Greene (Abstract No. 67)
11:00 A.M.—"Effect of Oxygen on the Active-Passive Behavior of Stainless Steel" by N. D. Greene (Abstract No. 68)

11:30 A.M.—"Kinetics of Redox Reactions on Passive Electrodes" by A. C. Makrides (Abstract No. 69)
12:30 P.M.—Corrosion Division Luncheon and Business Meeting, Castillian Room, Shamrock Hilton

ELECTRODEPOSITION (Cont'd)

Metal Deposition, with D. G. Foulke presiding

(GRECIAN ROOM, Shamrock Hilton, take right Promenade, then turn left)

9:00 A.M.—"Effect of Organic Compounds on the Codeposition of Hydrogen with Nickel" by J. R. Goodwyn and T. C. Franklin (Abstract No. 101)
9:30 A.M.—"Mechanism of Addition Agent Reaction in Bright Nickel Deposition" by S. E. Beacom and B. J. Riley (Abstract No. 102)
10:00 A.M.—"Electrodeposition of Iridium" by E. L. MacNamara (Abstract No. 103)
10:30 A.M.—"Electrodeposition of Pure Copper" by Sidney Barnartt (Abstract No. 104)
11:00 A.M.—"Electrodeposition of High-Purity Chromium from Electrolytes Containing Fluoride or Fluosilicate" by N. E. Ryan (Abstract No. 105)
11:30 A.M.—"Measurement of Stress in Very Thin Electrodeposits" by H. Watkins and A. J. Kolk (Abstract No. 106)
12:30 P.M.—Electrodeposition Luncheon and Business Meeting, Terrace, Shamrock Hilton.

ELECTRONICS—SEMICONDUCTORS (Cont'd)

Surfaces, with R. Hurd presiding

(EMERALD ROOM, Shamrock Hilton, off main Lobby)

9:00 A.M.—"Nuclear Magnetic Resonance of Water Adsorbed on Silicon" by C. G. McCormick and G. K. Walters (Abstract No. 158)
9:20 A.M.—"The Retention of Water by the Real Silicon Surface" by S. S. Baird (Abstract No. 159)
9:40 A.M.—"D-C Field and Noise Measurements on Silicon" by B. R. Pagel (Abstract No. 160)
10:00 A.M.—"Variation with Frequency of the Transverse Impedance of Semiconductor Surfaces" by F. Berz (Abstract No. 161)
10:20 A.M.—"Differential Capacity and Surface Conductivity of the Silicon Electrolyte Phase Boundary" by R. M. Hurd, P. T. Wrotenbery, and Don Arnold (Abstract No. 162)
10:40 A.M.—Recent News Papers. Titles and Short Abstracts will be available at the Registration Desk.

WEDNESDAY P.M., Oct. 12, 1960

BATTERY (Cont'd)

Nickel-Cadmium, with J. C. White presiding

(AZALEA ROOM, Exhibit Hall, entrance on Holcombe Blvd.)

2:00 P.M.—"High Energy: Weight Ratio, Nickel Cadmium Cells" by J. C. Duddy and A. J. Salkind (Abstract No. 30)
2:30 P.M.—"Formation of Porous Metal Plates by Electrolytic Reduction under Controlled Pressures" by C. M. Shepherd and H. C. Langelan (Abstract No. 31)
3:00 P.M.—"The Forming Process in Nickel Positive Electrodes" by Donald Tuomi (Abstract No. 32)

3:40 P.M.—"Electrochemical Behavior of the Semi-charged Nickel Oxide Electrode" by B. E. Conway and P. L. Bourgault (Abstract No. 33)

CORROSION (Cont'd)

Passivity (Cont'd), with M. Stern presiding

(CONTINENTAL ROOM, Shamrock Hilton, off Main Lobby)

2:00 P.M.—"Corrosion Behavior and Passivity of Nickel-Chromium and Cobalt-Chromium Alloys" by A. P. Bond and H. H. Uhlig (Abstract No. 72)

2:30 P.M.—"Anodic Polarization and Passivity of Ni and Ni-Cu Alloys in Sulfuric Acid" by J. Osterwald and H. H. Uhlig (Abstract No. 71)

3:00 P.M.—"Relation of Electron Configuration to Passivity in Cr-Ni-Fe Alloys" by H. G. Feller and H. H. Uhlig (Abstract No. 73)

3:25 P.M.—Ten-minute intermission

3:35 P.M.—"Critical pH and Critical Current Density for Passivity in Metals" by H. H. Uhlig (Abstract No. 70)

ELECTRODEPOSITION (Cont'd)

Alloy Plating, with D. R. Turner presiding

(GRECIAN ROOM, Shamrock Hilton, take right Promenade, then turn left)

2:00 P.M.—"Influence of Thiourea on the Deposition of Iron-Nickel Films" by R. D. DeMars (Abstract No. 107)

2:30 P.M.—"Influence of Substrates on Thin Magnetic Films Electrodeposited in a Magnetic Field" by M. Lauriente and F. X. McNally (Abstract No. 108)

3:00 P.M.—"Electrodeposition of Cobalt-Molybdenum Alloys" by Albertine Krohn and T. M. Brown (Abstract No. 109)

3:30 P.M.—"Composition and Thickness Effects on Magnetic Properties of Electrodeposited Thin Nickel-Iron Films" by Irving Wolf (Abstract No. 110)

4:00 P.M.—"Effect of Plating Parameters on the Structure and Magnetic Properties of Co and Co-Ni Alloys" by I. M. Croll and H. F. Quinn (Abstract No. 111)

4:30 P.M.—"Electrodeposition of Nickel-Cobalt Alloys from the Pyrophosphate Bath" by Vasanta Sree and T. L. Rama Char (Abstract No. 112)

ELECTRONICS—SEMICONDUCTORS (Cont'd)

Surfaces (Cont'd), with P. H. Keck presiding

(EMERALD ROOM, Shamrock Hilton, off main Lobby)

2:00 P.M.—"Characteristics of the {111} Surfaces of the III-V Intermetallic Compounds, II. Effect of Surface Active Agents" by M. C. Lavine, M. C. Finn, and H. C. Gatos (Abstract No. 163)

2:20 P.M.—"High-Temperature Oxidation Studies on the (111) and the (111) Surfaces of InSb and GaAs" by T. R. Perry, J. G. Harper, and D. P. Miller (Abstract No. 164)
2:40 P.M.—"Properties and Reactions of Stain Films on Silicon" by Allen Gee (Abstract No. 165)
2:55 P.M.—"The Study of Surface Contamination of Semiconductors by Radiochemical Techniques" by G. B. Larrabee (Abstract No. 166)
3:15 P.M.—"Encapsulation of Silicon Diodes in Low Melting Glass, I. Materials and Processes" by I. L. Kalnin and A. P. Pisarchik (Abstract No. 167)
3:40 P.M.—"Encapsulation of Silicon Diodes in Low Melting Glasses, II. Electrical Characteristics" by W. F. J. Hare (Abstract No. 168)
4:05 P.M.—Recent News Papers. Titles and Short Abstracts will be available at the Registration Desk.

THURSDAY A.M., Oct. 13, 1960

CORROSION (Cont'd)

Dissolution of Metals and Semiconductors, with C. V. King presiding

(CONTINENTAL ROOM, Shamrock Hilton, off Main Lobby)

9:00 A.M.—"Factors Influencing the Rates of Surface Processes" by A. C. Riddiford (Abstract No. 76)
9:50 A.M.—"Dissolution of Copper in Sulfuric Acid Solutions" by D. P. Gregory and A. C. Riddiford (Abstract No. 77)
10:20 A.M.—Ten-minute intermission
10:30 A.M.—"Kinetics of the Reaction between Copper and Aqueous Ammonia" by J. S. Stanley and J. A. Radley (Abstract No. 78)
11:00 A.M.—"Dissolution of Copper in Ferric Chloride Solutions" by H. M. Ferrari and M. J. Sinnott (Abstract No. 79)
11:30 A.M.—"Characteristics of the {111} Surfaces of the III-V Intermetallic Compounds, III. Effect of Cold Work on Dissolution" by H. C. Gatos and M. C. Lavine (Abstract No. 80)

THURSDAY P.M., Oct. 13, 1960

CORROSION (Cont'd)

Dissolution of Metals and Semiconductors (Cont'd), with C. V. King presiding

(CONTINENTAL ROOM, Shamrock Hilton, off Main Lobby)

2:00 P.M.—"A Simple Method for Monitoring the Chemical Etching Rate of Germanium and Silicon" by D. R. Turner (Abstract No. 81)
2:30 P.M.—"Chemical Etching of Germanium, I. Comparison of the Etching of Germanium and Silicon in Solutions of HF-HNO_3" by B. Schwartz and H. Robbins (Abstract No. 82)
3:00 P.M.—"Chemical Etching of Germanium, II. The System HF, H_2O_2, H_2O" by H. Robbins and B. Schwartz (Abstract No. 83)
3:30 P.M.—"Steady-State Liquid-Solid Interface Reactions as Applied to Silicon Etching by HNO_3-HF-H_2O" by J. J. Grossman (Abstract No. 84)

4:00 P.M.—"Magnitude of IR-drop Corrections in Electrode Polarization Measurements Made with a Luggin-Haber Capillary" by Sidney Barnartt (Abstract No. 85)
4:30 P.M.—"Inhibition of the Corrosion of Pure Aluminum in Hydrochloric Acid Solutions" by J. Sundararajan and T. L. Rama Char (Abstract No. 85A)

ELECTRODEPOSITION (Cont'd)

General Session, with D. Trivich presiding

(GRECIAN ROOM, Shamrock Hilton, take right Promenade, then turn left)

9:00 A.M.—"Electrical Behavior of Passive Iron" by J. L. Ord and J. H. Bartlett (Abstract No. 113)
9:30 A.M.—"Anodic Properties of Nickel under Nonpassivating Conditions" by Marvin Kronenberg, Ernest Yeager, and Frank Hovorka (Abstract No. 114)
10:00 A.M.—"Effect of Cathode Vibration on Overpotential of Lead in $NaHPbO_2$ and in Alkaline Lead Tartrate Solutions" by J. L. Griffin and L. O. Case (Abstract No. 115)
10:30 A.M.—"Some Observations of Copper Deposits on Single Crystals of Copper" by I. B. Giron and Fielding Ogburn (Abstract No. 116)
11:00 A.M.—"Electroplating of Silver onto Aluminum" by V. A. Nelson (Abstract No. 117)
11:30 A.M.—"Porosity Measurements on Gold-Plated Copper" by M. S. Frant (Abstract No. 118)

Abstracts

BATTERY

Abstract No. 1

Ambient Temperature Fuel Cells

H. F. Hunger, U.S. Army Signal Research and Development Lab., Ft. Monmouth, N. J.

Fuel cells operating on hydrogen or partially oxygenated organic compounds at room temperature and close to atmospheric pressure, utilizing alkaline electrolytes in the form of aqueous solutions or anion exchange membranes, and reaction mechanisms are discussed. The methods to achieve good electrode performance by proper selection of electrode carriers and preparation of catalysts are shown. Advantages and disadvantages observed with ion exchange membrane electrolytes are described. Special emphasis is given to cells operating on liquid fuels.

Abstract No. 2

Electrode Kinetics of Various Redox Couples for Fuel Cell Use

A. P. Bond and **D. Singman,** Diamond Ordnance Fuze Labs., Ordnance Corps, Washington 25, D. C.

Electrode kinetics of several oxidation-reduction couples of possible use in a redox fuel cell were investigated by means of polarization measurements at platinum, carbon, titanium, and tantalum electrodes. The Ti^{+++}-TiO^{++} and Br_2-Br^- couples appear most suitable from the electrochemical standpoint for use

at the anode and cathode, respectively, of a redox fuel cell.

Abstract No. 3

Investigation of the Electrochemical Characteristics of Organic Compounds, VIII. Hydrazine and Hydroxylamine Compounds

R. Glicksman, Semiconductor and Materials Div., Radio Corp. of America, Somerville, N. J.

The electrochemical characteristics of various organic hydrazine and hydroxylamine derivatives are presented, and their use as anode materials in galvanic cells is considered. The anode potential of these compounds is dependent on the type and position of substituent groups in the molecule as well as the pH of the electrolyte. The effect of the first two factors on the anode potential is interpreted in terms of the electron density distribution in the molecule.

Abstract No. 4

Factors Affecting the Discharge Characteristics of Thermal Cells

C. W. Jennings, Sandia Corp., Sandia Base, Albuquerque, N. Mex.

Mechanisms contributing to the voltage decrease under load of thermal cell systems of the type Ca/LiCl, $KCl/CaCrO_4/Ni$ at 425°-550°C are discussed. An explanation is given for the variation in cell life to a given cut off voltage with amount and composition of electrolyte.

Abstract No. 5

Recent Studies on Ammonia Battery Systems

Otto Adlhart and **H. R. Knapp,** U.S. Army Signal Research and Development Lab., Ft. Monmouth, N. J.

Electrochemical studies on ammonia battery systems are described. Properties of several ammonia electrolytes are characterized and compared to aqueous and other nonaqueous electrolytes. Polarization curves for several metallic anodes in suitable electrolytes are presented. Construction details for high and low rate structures are presented, and typical cell discharge data are discussed.

Abstract No. 6

The Photogalvanic Effect in Inorganic Oxidation-Reduction Systems, I. The Iodine-Iodide System

H. N. Seiger (present address: R&D Lab., Alkaline Battery Div., Gulton Industries, Inc., Metuchen, N. J.) and **R. A. Marcus,** Polytechnic Institute of Brooklyn, 333 Jay St., Brooklyn 1, N. Y.

The photopotential of an iodide-iodine-platinum electrode half-cell was investigated in the linear current-potential region for various intensities, concentrations, wave lengths, and window-electrode distances. The effect was proportional to light intensity at low intensities and roughly paralleled the absorption spectrum of the electrolyte. The slopes of the i-E plots were substantially increased by illumination. These and other facts are explained here in terms of an enhanced convection. The sign of the small photopotential at $i = 0$ is consistent with the observed temperature increase which accompanied the irradiation.

Abstract No. 7

Investigation of the Electrochemical Characteristics of Organic Compounds, VII. Organic Positive Iodine and Aliphatic Azo Compounds

R. Glicksman and **C. K. Morehouse,** Semiconductor and Materials Div., Radio Corp. of America, Somerville, N. J.

The electrochemical characteristics of organic positive iodine compounds such as iodosobenzene and iodoxybenzene, and aliphatic azo compounds such as azodicarbonamide and N,N'-dichloro-azodicarbonamidine in various electrolytes are presented. Performance characteristics of magnesium and aluminum dry cells containing these organic oxidizing agents as cathode materials are also presented.

Abstract No. 8

Stability and Solubility of Silver Oxide Electrodes in Alkaline Electrolytes

R. F. Amlie and **Paul Ruetschi,** Carl F. Norberg Research Center, Electric Storage Battery Co., Yardley, Pa.

The decomposition reaction $2AgO \rightarrow Ag_2O + \frac{1}{2} O_2$ in alkaline electrolytes was investigated using a microvolumetric technique. The decomposition rate increases with increasing hydroxyl ion concentration. The solubilities of Ag_2O and AgO in alkaline electrolyte were studied with a polarographic technique using a rotating platinum microelectrode. Evidence is presented that AgO does not produce soluble divalent silver species in contact with alkaline electrolytes. However, AgO slowly self-discharges or decomposes to Ag_2O, and it is the latter which is slightly soluble.

Abstract No. 9

The Magnesium-m-Dinitrobenzene Cell

G. S. Lozier, R. Glicksman, and **J. B. Eisen,** Semiconductor and Materials Div., Radio Corp. of America, Somerville, N. J.

m-Dinitrobenzene was selected from the many possible organic materials for a detailed study as the cathode in magnesium primary cells because of its availability and favorable electrochemical properties. An analysis of the cell reaction has shown that for optimum cell performance a carbon with a very high water retention which maintains a high electrical conductivity is required. The impedance and delayed action characteristics of Mg-m-dinitrobenzene cells are due primarily to the magnesium anode and are similar to comparable size Mg-MnO_2 cells. The magnesium-m-dinitrobenzene cell has a capacity over 90 whr/lb at practical discharge rates.

Abstract No. 10

The Influence of the Active Surface on the Cathodic Reduction of MnO_2

N. C. Cahoon, Battery Development Lab., Union Carbide Consumer Products Co., Cleveland, Ohio, and

M. P. Korver, Research Lab., Union Carbide Consumer Products Co., Parma, Ohio

The surface area of samples of manganese dioxide is shown to be an important factor in influencing its behavior. Four samples of MnO_2 of widely different origins— electrolytic, activated, natural ore, and synthetic pyrolusite—are used as examples. The rates of the recuperation reaction at temperatures of 21°-50°C are shown to be related to the total surface area of the oxides by a complex relation, dependent on the temperature and other factors. The product of the reaction MnOOH develops on the surface and in the pores of the original MnO_2 particle, thus increasing the diameter and resulting in reduced pore volume, respectively. The MnOOH made under these conditions from all four starting materials appears as rod-shaped units in electron micrographs.

Abstract No. 11

Impedance of Dry Cells and Batteries

R. J. Brodd, National Bureau of Standards, Washington, D. C.

The impedance of Lechanché, mercury, alkaline MnO_2, nickel cadmium, and lead acid cells was measured between 50 cps and 50 kps. The impedance of several Leclanché batteries was also measured between 50 cps and 50 kps. Results are interpreted based on the assumption that the electrode reactions are relaxation processes.

Abstract No. 12

Recharging of Leclanché Dry Cells

W. S. Herbert, Research Center, Electric Storage Battery Co., Yardley, Pa.

The recharging of Leclanché dry cells was studied from the standpoint of the reactions occurring in the cell during both the discharge and charging operations. It was found that constant potential charging in the range of 1.7-2.1 v was most satisfactory. Constant current charging can result in damage to the cells and is to be avoided especially for cells arranged in series. Suitable constant potential charging circuits were developed. Recharging can extend the useful life of dry cells if the conditions are selected carefully.

Abstract No. 13

Is the Lead-Acid Battery Obsolete?

Paul Ruetschi, Carl F. Norberg Research Center, Electric Storage Battery Co., Yardley, Pa.

A brief history of the lead-acid battery from its invention by Planté in 1860 to the present time, including a discussion of major advances in technology, is outlined. Today U.S. production figures for different battery systems are given, and the various systems are

compared with regard to availability of raw materials, economy, and specific application. The possible replacement of lead-acid batteries by new portable power sources such as fuel cells, thermoelectric generators, and solar cells is discussed, and the conclusion is drawn that the lead-acid battery will be used for years to come wherever cheap packaged power is required.

Abstract No. 14

How Lead Becomes a Battery

R. Jardine and **S. K. Lessey,** Electric Storage Battery Co., Rising Sun and Adams Ave., Philadelphia 20, Pa.

The paper presents the basic principles of the conversion of lead into Planté storage battery plates. The fact that many methods have been used is stated, and a few commercially used methods are described. The large variety of plate types that have been used is mentioned, and the ones now manufactured are discussed. Commercial battery types and their service abilities and records are illustrated by the use of slides.

Abstract No. 15

The Anodic Oxidation Rate of Pure Lead in Sulfuric Acid

R. A. Baker, Bell Telephone Lab., Inc., Murray Hill, N. J.

The oxidation rate of lead in sulfuric acid solution at polarizations above the $PbO_2/PbSO_4$ potential has been measured at 15°, 30°, and 45°C by a new, nondestructive technique. The rate, at constant temperature, depends exponentially on the polarization. Following an initial transient, the rate at constant temperature and polarization is constant with time. The corrosion product consists of both α- and β-PbO_2 and the attack on the lead is uniform.

Abstract No. 16

Planté, Pourbaix, and Passivation

Jeanne Burbank, U.S. Naval Research Lab., Washington 25, D. C.

Planté plate formation is discussed from the viewpoint of corrosion vs. passivation. The experimental observations of passivation phenomena of pure lead metal under anodic polarization in acid solutions are summarized. The Planté formation techniques are related to these studies and the practical application of the Pourbaix electrochemical phase diagrams to Planté formation is outlined.

Abstract No. 17

Mechanisms of the Electrode Reactions in Lead Accumulators

W. F. K. Wynne-Jones, Chemistry Bldg., King's College, University of Durham, Newcastle-upon-Tyne, England

The over-all reaction of the lead accumulator is given uniquely by the equation: $Pb + PbO_2 + 2H_2SO_4 = 2PbSO_4 + 2H_2O$. Intermediate nonequilibrium, nonelectrochemical steps cannot participate in the electrode reactions which are therefore restricted to: formation of $PbSO_4$ on Pb, oxidation of $PbSO_4$ to PbO_2, reduction of $PbSO_4$ to Pb, reduction of PbO_2 to $PbSO_4$, evolution of O_2 on PbO_2, and the evolution of H_2 on Pb. Constant current and constant potential methods have yielded important information on the detailed mechanisms. The exchange between plumbous ions in solution and plumbic ions in the solid phase has shown the importance of diffusion in the solid phase. The rate of exchange is controlled by conditions of preparation, and the more reactive α-PbO_2 is found to exchange more rapidly than the normal β-PbO_2.

Abstract No. 18

(There is no Abstract No. 18)

Abstract No. 19

Formation Studies of Lead-Acid Battery Plates Using the Electron Microscope

J. E. Buskirk, P. D. Boyd, and **V. V. Smith,** Delco-Remy Div., General Motors Corp., Muncie, Ind.

Micrographs to be shown include lead oxide and the surfaces of cured plates, plates soaked in sulfuric acid solutions, and plates formed at two different rates. The electron microscope has promise of becoming a useful tool for battery research.

Abstract No. 20

Electrode Potentials and Thermal Decomposition of α- and β-PbO_2

R. T. Angstadt and **Paul Ruetschi,** Carl F. Norberg Research Center, Electric Storage Battery Co., Yardley, Pa.

Samples of α- and β-PbO_2 were subjected to thermal decomposition in the temperature range from 100° to 580°C. The two modifications of PbO_2 have different thermal stability and decompose into different intermediate materials. The crystal structures of the intermediate products have been studied. Electrode potentials of α- and β-PbO_2 were measured in sulfuric acid and perchloric acid solutions. At *p*H values below 3 the potentials in solution containing $SO_4^{=}$ ion correspond to the equation

$$PbO_2 + H_2SO_4 + 2H^+ + 2e \rightarrow PbSO_4 + 2H_2O$$

However, at higher pH values the experimental values differ greatly from the ones derived theoretically.

Abstract No. 21

Some Important Factors That Influence the Composition of Positive Plate Material

V. H. Dodson, Electric Autolite Co., Toledo, Ohio

The composition of positive plate material formed (*a*) from positive pastes of various densities, (*b*) in aqueous sulfuric acid solutions of various specific gravities, (*c*) at various rates (current densities), and (*d*) at various temperatures has been studied. Variations in these conditions not only influence the total PbO_2 content of the formed material but also the ratio of α-PbO_2 to β-PbO_2 in the formed material.

Abstract No. 22

Composition and Performance of Positive Plate Material

V. H. Dodson, Electric Autolite Co., Toledo, Ohio

The change in the composition of the positive material during (*a*) initial 20-hr discharge test, (*b*) successive 20-hr tests, (*c*) high rate discharge at 80° and 0°F, and (*d*) stand at room temperature has been studied. The performance of the positive plate under the conditions of these tests can be related to the total PbO_2 and α-PbO_2 content of the positive material.

Abstract No. 23

The Next Hundred Years

E. Willihnganz, C&D Div., Electric Autolite Co., Conshohocken, Pa.

The next hundred years of the storage battery can be predicted only in a general way. A review of the course of development of other inventions compared with a history of the storage battery up to the present indicates what is liable to occur. A review of the field of electrochemical power sources tells in which direction progress might be made. This also helps predict what the future may hold and is valid if nothing unforeseen develops.

Abstract No. 24

Ionic Conductivity of Silver Iodide Pellets for Solid Electrolyte Batteries

L. N. Mrgudich (present address: U.S. Army Signal R&D Lab., Ft. Monmouth, N. J.), Lab. for Insulation Research, Massachusetts Institute of Technology, Cambridge, Mass.

Silver amalgam electrodes were found to provide polarization-free contacts for the measurement of the

ionic conductivity of compressed AgI powder pellets. Correlation of the conductivity data with x-ray diffraction studies established the presence of a deformed hexagonal phase as an important factor in determining pellet conductivity. Deformation can be induced by compression, but care must be taken to avoid transformation into the face-centered cubic phase with some resultant decrease in conductivity. Preliminary evidence is presented that hexagonal deformation can be induced by proper control of preparation or by suitable thermal or mechanical pretreatment of the AgI powder.

Abstract No. 25

The Ag/AgCl/ICl Solid Electrolyte Cell System

D. M. Smyth and **C. H. Tompkins,** Sprague Electric Co., North Adams, Mass.

Solid electrolyte batteries based on the Ag/AgCl/ICl system can sustain higher current drains and have improved high-temperature stability compared with batteries based on the Ag/AgCl/Cl_2 system previously described. In these systems the iodine monochloride and chlorine cathode vapors are furnished by the dissociation of $KICl_2$ and $KICl_4$, respectively. High-temperature aging of the ICl system eventually results in a stable voltage plateau indicative of an iodine vapor cathode.

Abstract No. 26

An Analytical Representation of the Characteristics of Commercial Secondary Batteries

S. M. Selis and **C. R. Russell,** Research Labs., General Motors Corp., Warren, Mich.

In 1897 Peukert presented an analytical function which related the constant discharge current of lead-acid batteries to the time actually required for this discharge. It has been found that this function will describe the discharge of modern commercial lead-acid batteries as well as batteries with alkaline electrolytes. In addition, an algebraic relationship is presented which describes battery capacity as a function of the constant discharge current (or discharge time). Modifications to include a term for ambient temperature are also considered.

Abstract No. 27

Float Characteristics of the Lead-Calcium Cell

Jeanne Burbank and **C. P. Wales,** U.S. Naval Research Lab., Washington 25, D. C.

An analysis of the factors determining successful float of lead-calcium cells is presented. True float operation is described, and the individual plate behavior is analyzed. Polarization curves of the individual plates

at various states of charge have been determined. It has been observed that a successfully floating cell has a characteristic excess of positive plate capacity, that the positive "floats" on the overvoltage curve of its charging reaction, and the negative floats on its hydrogen overvoltage curve. The developed plate areas must be such that these requirements are met simultaneously by the plates of a given cell if it is to perform satisfactorily in float service.

Abstract No. 28

The Silver-Silver Oxide Electrode, I. Anodic Oxidation in Alkaline Solutions

C. P. Wales, U.S. Naval Research Lab., Washington 25, D. C.

Silver electrodes were oxidized anodically in KOH at various charging currents. The electrodes were given both partial and complete charges. Oxidation was highly efficient. Discharge of partially charged electrodes often showed a potential plateau intermediate between the AgO/Ag_2O and Ag_2O/Ag plateaus. The quantity of charge accepted at each potential level was examined, as well as the form of the potential curves. The oxidation and reduction of the electrode is discussed.

Abstract No. 29

Electrode Phenomena of the Silver-Silver Oxide System in the Alkaline Battery

Shiro Yoshizawa and **Zenichiro Takehara,** Dept. of Industrial Chemistry, Faculty of Engineering, Kyoto University, Kyoto, Japan

Electrode phenomena of the silver-silver oxide system in an alkaline battery and effects of small quantities of various cations when added to the silver electrode were examined by means of the electron-microscope, x-ray diffraction, oscilloscopic determination of the decay and growth of overpotential, and current potential relationships. Results show that, in the case of the charge, Ag_2O and then AgO form, and the underlying Ag crystals expand owing to diffusion of oxygen anion; on discharge, the reverse reaction may occur.

Abstract No. 30

High Energy: Weight Ratio, Nickel Cadmium Cells

J. C. Duddy and **A. J. Salkind,** Carl F. Norberg Research Center, Electric Storage Battery Co., Yardley, Pa.

Conventional nickel cadmium cells contain the active materials in either porous sintered nickel plaques or in nickel or nickel-plated steel pockets or tubes. A new process, adaptable to continuous methods of production, has been developed in which the active and conductive materials are dispersed in a microporous plastic structure. Cells with the high energy to weight ratio of 40

whr/kg have been constructed. Cell volumes are equal to those of the sintered plate design for equivalent capacities.

Abstract No. 31

Formation of Porous Metal Plates by Electrolytic Reduction under Controlled Pressures

C. M. Shepherd and **H. C. Langelan,** U.S. Naval Research Lab., Washington 25, D. C.

Metal plates having porosities from 40 to 90% were produced by the reduction of pasted metal compounds in an electrolytic cell. The porosity was a function of the physical pressure applied to the plate assembly during reduction. Successful formation depended on effective pasting and the proper selection of compound and electrolyte. Nearly all metals that electroplate at high efficiencies can be formed in this manner. The relationships between particle size, water content, tap density, and pasting conditions have been studied.

Abstract No. 32

The Forming Process in Nickel Positive Electrodes

Donald Tuomi, Thomas A. Edison Research Lab. Div., McGraw-Edison Co., West Orange, N. J.

The formation of nickel positive electrodes has been studied by a combination of x-ray diffraction and microscopy techniques. The distinct chemical phases encountered are described. The complexity of the process is illustrated.

Abstract No. 33

Electrochemical Behavior of the Semi-charged Nickel Oxide Electrode

B. E. Conway and **P. L. Bourgault,** Dept. of Chemistry, University of Ottawa, Ottawa, Ont., Canada

The kinetic behavior of semi-charged "$NiO_{1.25}$" electrodes has been studied by emf decay measurements which enable a mechanism of charging and oxygen evolution to be formulated. Optimum charging is shown to occur at high rates on the $NiO_{1.25}$ electrode, oxygen evolution being preferred at low potentials. Reversible and mixed potentials of the nickel oxide electrode are distinguished, and it is shown that previous data refer to mixed potentials. A kinetic analysis enables the true reversible potentials to be evaluated.

CORROSION

Abstract No. 34

A Hypothesis for the Uncoupling Shift Observed in the Iron-Tin System in Citric Acid

W. R. Buck, III, A. N. J. Heyn, and **Henry Leidheiser, Jr.,** Virginia Institute for Scientific Research, Richmond, Va.

When electrical contact is broken between electrodes of iron and tin in citric acid containing dissolved tin, the potential of the iron moves in the noble direction for a short time and then in the active direction for a long time. This phenomenon, first observed by Koehler, is given the name "uncoupling shift." It has been studied with pure iron in boiling 0.2M citric acid. Potential measurements, chemical studies, and electron microscope and electron diffraction observations relating to the effect have been made.

Abstract No. 35

Effect of Tin Ion Complexing Substances on the Relative Potentials of Tin and Steel in Oxygen Free Acid Media

A. R. Willey, Research and Technical Dept., American Can Co., Barrington, Ill.

Half-cell potentials of tin and steel have been measured in a variety of organic and inorganic acids in the absence of oxygen. Tin ion was varied from 0 to 1M and pH from zero to about 6.0. Similar measurements were made in a number of fruit juices. Only in the presence of a strong complexing substance is tin anodic or protective to steel. The data are helpful in studying corrosion problems connected with the tin-plate container.

Abstract No. 36

Oxide Films on Tin Plate

M. Falkenhagen and **J. D. Bode,** Graham Research Lab., Jones & Laughlin Steel Corp., Pittsburgh 30, Pa.

The nature of oxide films on tin plate is revealed by electron micrographic, x-ray and electron diffraction, and spectrographic investigations. Details of the film stripping technique and microscopic examination are described. These studies indicate changes in film characteristics with time, including auxiliary and overgrowths, and different shadowing techniques reveal the microstructure.

Abstract No. 37

Some Factors Affecting the Surface Chromium Content of Electrochemically Treated Tin Plate

P. R. Carter, U.S. Steel Corp., Monroeville, Pa.

The relation among current density, total coulombs, solution temperature and pH, and chromium content of the treatment film for the cathodic and the cathodic-anodic dichromate electrochemical treatments is discussed as well as the relation between film stability and the chromium content. The previous theory of what occurs during cathodic treatment in sodium dichromate solutions is modified to conform to the new data.

Abstract No. 38

Use of Polarization Methods in the Determination of the Rate of Corrosion of 3003 Aluminum in Anaerobic Acid Media

S. Evans and **E. L. Koehler,** Central Research and Engineering Div., Continental Can Co., Chicago, Ill.

The variation of the corrosion potential of aluminum with *p*H in citrate buffer solutions in the *p*H range 2.5-6.4 was found to be analogous to that for hydrogen electrode. The rate of corrosion over this *p*H interval was practically constant. It was found that the overvoltage-intercept method could be used to determine accurately the rate of corrosion of the aluminum from cathodic polarization data in the citrate buffer solutions and in a variety of other acid media. The polarization resistance method was equally applicable when using an experimentally determined value for the cathodic Tafel-slope and assuming an identical anodic Tafel-slope.

Abstract No. 39

Use of Polarization Methods in the Determination of the Rate of Corrosion of Aluminum Alloys in Anaerobic Food Media

E. L. Koehler and **S. Evans,** Central Research and Engineering Div., Continental Can Co., Chicago, Ill.

The corrosion rate of aluminum in food media is generally too low to be determined accurately by methods such as measurement of weight loss and hydrogen evolution rates. The use of polarization methods has been investigated and has been found to be particularly valuable. In media of very low corrosiveness, Tafel-type anodic curves are obtained which can be used successfully both to determine corrosion rates by the overvoltage-intercept method and to give a slope which is useful in the polarization resistance method. Where an anodic Tafel-type curve cannot be determined experimentally a calculated anodic curve can be used successfully. In all cases investigated, the slope was found to have a numerical value approximately equal to that for the cathodic curve.

Abstract No. 40

The Oxidation of Tin, II. Morphology and Mode of Growth of Oxide Films on Pure Tin

W. E. Boggs, P. S. Trozzo, and **G. E. Pellissier,** Applied Research Lab., U.S. Steel Corp., Monroeville, Pa.

The oxide films formed during a study of tin oxidation kinetics were examined with an electron microscope. The oxide nucleates at numerous sites on the tin surface and grows laterally. The morphology and mode of growth of the oxide crystallites are dependent upon the oxygen pressure. During the growth of oxide

platelets, cavities are observed developing at the oxide-metal interface. These cavities eventually reduce the area of contact between oxide and metal by as much as one-third.

Abstract No. 41

The Oxidation of Tin, I. Kinetics of Oxidation of Pure Tin and the Effects of Temperature and Oxygen Pressure

W. E. Boggs, R. H. Kachik, and **G. E. Pellissier,** Applied Research Lab., U.S. Steel Corp., Monroeville, Pa.

The rates of oxidation of pure tin foil have been determined over a range of temperatures and oxygen pressures. At pressures over 1 mm, the oxidation proceeds in three stages: at first, the rate is low, but increases rapidly to a maximum; then it begins to decrease, following a direct logarithmic rate law; and finally, it becomes erratic, either increasing or leveling off. At pressures under 1 mm, the oxidation rate appears to be controlled initially by the dissociation of oxygen at the metal surface.

Abstract No. 42

The Oxidation of Tin, III. Mechanisms of Oxidation of Pure Tin

W. E. Boggs, Applied Research Lab., U.S. Steel Corp., Monroeville, Pa.

During the growth of tin oxide at oxygen pressures over 1 mm, the initial, increasing rate of oxidation is a result of the nucleation and lateral growth of oxide platelets. The subsequent logarithmic rate is believed to be caused by the growth of cavities at the oxide metal interface. The eventual erratic and nonreproducible behavior may be caused by the occasional collapse of the oxide skin over the cavities.

Abstract No. 43

Microtopography of Oxide Films Formed on Tantalum

R. E. Pawel, J. V. Cathcart, and **J. J. Campbell,** Metallurgy Div., Oak Ridge National Lab., Oak Ridge, Tenn.

Optical and electron microscopy were used to characterize the surface of tantalum specimens oxidized at temperatures ranging from 300° to 700°C. Oxide platelets grow during initial oxidation and not during cooling from the reaction temperature. At higher temperatures, both platelets and nodules serve as preferred sites for blister and crack formation in the oxide and thus play an important role in the transition from the protective to the nonprotective stage of oxidation of tantalum.

Abstract No. 44

Interaction between Copper and Gas Discharge Products Condensed at Very Low Temperatures

Jerome Kruger and **W. J. Ambs,** National Bureau of Standards, Washington 25, D. C.

The reaction between oxygen and oxygen-nitrogen mixtures passed through a 2450 mc electrodeless discharge and copper was studied with the ellipsometer. The free radicals or other active species produced by the discharge were trapped out on the copper surface at 4.2°K and allowed to react upon warming. Reaction at 77° and 300°K was also studied. The influence of the addition of varying amounts of nitrogen, condensation temperature, and crystallographic orientation of the copper surface was studied.

Abstract No. 45

Copper Oxides on the Surface of Gold Plate

M. S. Frant and **R. Rajaraman,** Research Division, AMP Inc., Harrisburg, Pa.

Significant quantities of copper oxides were found on the surface of electroplated gold specimens after relatively short heating times at temperatures as low as 125°. Both cuprous and cupric oxides were measured using coulometric reduction techniques. Data are given on the effect of gold thickness, temperature, and type of deposit. The results are shown to be consistent with a mechanism involving diffusion of the copper to the surface, followed by oxidation.

Abstract No. 46

Oxidation of Copper between 250° and 450°C and the Growth of CuO "Whiskers"

E. A. Gulbransen, T. P. Copan, and **K. F. Andrew,** Research Labs., Westinghouse Electric Corp., Pittsburgh 35, Pa.

The results suggest that the oxidation of copper follows the cubic rate law between 250° and 450°C. Small embryonic whiskers of CuO were formed at 250°C after 6 hr of reaction. At 450°C, after 6 hr of reaction, a surface density of $10^6/cm^2$ of long, thin oxide whiskers was found. Calculations show that less than 1% of the oxygen reacted at 450°C resulted in the growth of oxide whiskers. It was concluded that the formation of oxide whiskers had no appreciable effect on the over-all kinetics of the oxidation of copper.

Abstract No. 47

Corrosion Rate of Fe in High-Temperature H_2O by an Electrical Resistance Method

A. J. Panson, Research Labs., Westinghouse Electric Corp., Pittsburgh 35, Pa.

The kinetics of the reaction between pure iron and water has been studied at temperatures up to 365°C.

The reaction was followed by determining the increase in electrical resistance with time of corroding samples. The resistance measurements were made while the samples were being reacted in a gold-plated autoclave. A sensitivity of about 70Å of film was achieved. Two hundred-hour experiments at 365°C resulted in reaction of 4000 to 7000Å of metal. The data fit the logarithmic rate law over the entire period at temperature.

Abstract No. 47A

Unusual Oxidation States Encountered in Corrosion Processes

E. C. Pitzer, Knolls Atomic Power Lab., General Electric Co., Schenectady, N. Y.

The industrially important metals are closely grouped near the center of a modified Meggers periodic table. Most of these metals are of variable valence. The end products of corrosion of most metals have been well characterized, but more information is needed on intermediate stages of oxidation. Examples of unusual oxidation states resulting from impressed voltages high enough to overcome the passive films on certain metals are discussed.

Abstract No. 48

Evidence for One-Electron Oxidation as Primary Electrode Reaction in Anodic Dissolution of Bivalent Metals

A. W. Davidson, University of Kansas, Lawrence, Kans.

The amount of metal that dissolves electrolytically from an anode of beryllium, magnesium, zinc, or cadmium in an aqueous electrolyte is usually considerably in excess of that predicted on the basis of Faraday's law. Whenever this is the case, a product of reduction can be found in the anolyte after electrolysis. These facts may be most readily explained in terms of the hypothesis that the primary anode reaction is oxidation of the metal to a unipositive ion with strong reducing properties.

Abstract No. 49

The Relative Stabilities of Oxidation States of Transitional Metals

G. W. Watt, Dept. of Chemistry, University of Texas, Austin, Texas

The stabilities of ionic species that participate in electrochemical and related processes are dependent on several characteristics including (*a*) properties of a specific metal ion, (*b*) nature of the bonded ligands, and (*c*) character of the metal-ligand bonds. The conditions under which one may produce, characterize, and stabilize oxidation states that are unusual in the sense that they are either higher or lower than those normally

encountered are discussed. The character of the metal-ligand bond is believed to control the mechanism of electrode reactions of metal ions.

Abstract No. 50

Valency of Ions Formed during Anodic Dissolution of Metals in Acids

M. E. Straumanis, Dept. of Metallurgical Engineering, University of Missouri, School of Mines and Metallurgy, Rolla, Mo.

The apparent valence of ions of active metals, going into solution anodically (in an acid as electrolyte) can be determined from the Faradaic current after the initial, self-dissolution rate has been subtracted from the total rate. However, this apparent valence corresponds to the true valence only in cases when the self-dissolution rate does not change while the anodic current is applied. Usually the rate decreases or increases during the flow of the current (diffusion effect). If this factor is disregarded, ion valencies of lower or higher value than the normal are calculated. Examples involving Zn, Al, Zr, Ti, and TiO_x alloys as dissolving anodes are discussed.

Abstract No. 51

The Difference Effect and Anodic Behavior of Zirconium Dissolving in Hydrofluoric Acid

M. E. Straumanis, W. J. James, and **W. C. Custead,** Depts. of Metallurgical and Chemical Engineering, University of Missouri, School of Mines and Metallurgy, Rolla, Mo.

Zirconium dissolving in hydrofluoric acid exhibited a positive difference effect of such an efficiency that the hydrogen volume developed by the internal polarization current was completely annihilated by the effect. The effect was independent of the concentration of the acid and was accompanied by a strong shift in potential of the Zr electrode toward noble values (passivation). The same occurred in the presence of salts of more noble metals: the rate of dissolution of Zr dropped (nearly to zero with Pt^{++} additions): the black hydride surface film disappeared and the Zr turned bright and shiny (passive Zr). The activity of Zr returned when the anodic current was cut off.

Abstract No. 52

The Difference Effect and the Chunk Effect

G. A. Marsh and **E. Schaschl,** Pure Oil Co. Research Center, Crystal Lake, Ill.

The corrosion rate of a metal such as steel varies as a function of current applied from an external source. An analysis of this corrosion-applied current relationship leads to a new theory on the mechanism of corrosion. By this theory, corrosion proceeds partly by the

removal of "chunks" of metal rather than by the removal of one atom at a time. The phenomenon on which the theory is based is called the "chunk effect." In certain acidic solutions the chunk effect accounts for over 50% of the loss of metal. This report also considers the relationship between the chunk effect and the positive and negative difference effects. The positive difference effect is known to be related to anodic polarization of a corroding metal. The negative difference effect, on the other hand, has not previously been adequately explained, and is shown here to be a manifestation of the chunk effect.

Abstract No. 53

(There is no Abstract No. 53.)

Abstract No. 54

Adsorption and Ion Exchange at the Corrosion Interface

G. H. Cartledge, Chemistry Div., Oak Ridge National Lab., Oak Ridge, Tenn.

To introduce the Symposium, consideration is directed to a number of problems connected with the interface between a metal and its environment that have, or may have, relevance to the corrosion process. Among these, adsorption obviously has an important role. It is discussed on the basis of experiments on the influence of adsorbed iodide ions or carbon monoxide on the polarization of iron in acidic solutions in the active region of potentials. Other data to be discussed derive from the cathodic polarization of passive iron in the presence of several inhibitors and in different atmospheres. From these measurements, electrochemical evidence for some new conceptions of the nature of the passive interface was obtained. Finally, it is shown that the passive film may exhibit ion-exchange properties toward certain ions.

Abstract No. 55

Proton Mobility in Liquids and Solids

B. E. Conway, Dept. of Chemistry, University of Ottawa, Ottawa, Ont., Canada

Rates of proton migration in liquids and solids can be determined from conductance and transference experiments. In certain solids, e.g., ice and hydrated nickelic oxide, there is evidence that proton transfer plays an important role in determining the conductivity of the solid. In metallic corrosion under conditions where hydrous oxide surface films are formed, the conductivity of the surface layer can be important in determining the corrosion rate and the onset of passivity. Investigation of the role of proton transfer processes (other than in hydrogen evolution) in electrochemical corrosion is therefore of importance.

Abstract No. 56

The Structure of the Corroding Interface

T. P. Copan, Research Labs., Westinghouse Electric Corp., Pittsburgh 35, Pa.

The structure of the corroding interface can be determined by an electron microscopic study of the crystal habit of the corrosion products formed in vapor phase chemical reactions. Three factors are important in determining the structure of the corroding interface on pure iron, two of which are related to the interface itself: (*a*) nature and activity of the corroding environment, (*b*) nature of the metal structure including impurities, defects, dislocations, precipitates, etc., and (*c*) stress pattern of the metal. Three types of nucleation centers are found in the corroding interface of iron: (*a*) point sources, 150-200Å in diameter of random distribution and a surface density up to $10^5/cm^2$; (*b*) small line sources, 100-200Å wide, up to 15,000Å long and a surface density up to $10^5/cm^2$; and (*c*) large line sources, 100-200Å wide, up to 100,000Å long and an undetermined surface density. The implications of the three types of corroding interfaces are discussed.

Abstract No. 57

Effects of Corrosion Films on Cathodic Processes

R. E. Meyer, Chemistry Div., Oak Ridge National Lab., Oak Ridge, Tenn.

An oxide film on a metal influences reduction processes at the surface in a number of ways which depend on the properties of the film. Three cases may be distinguished according to whether the film has low conductivity, high conductivity, or gross structural defects. Particular attention is paid to the first case, and the influence of film-thickness and inhomogeneities on the steady-state current is included. Expressions for the current as a function of potential and solution activity are given, again with particular attention to films of low conductivity. Transient effects are discussed briefly.

Abstract No. 58

Dissolution of Mild Steel in the System NH_4NO_3-HN_3-H_2O at 30°C

J. D. Goodrich and **Norman Hackerman,** Dept. of Chemistry, University of Texas, Austin 12, Texas

Rates ranged from near zero to almost 30,000 mdd, but the variation did not correlate effectively with metal composition or with grain size. Mechanical stress or quenching from 1000°C increased the rate of those metals corroding slowly, the relationship between stress and rate being discontinuous. Solution composition had a mild effect on the rates. No cracking or pitting was observed. The reduction reaction was in part, if not wholly, nitrate to nitrite. The corrosion

product was nonprotective and often nonadherent and appears to be a hydrated or ammoniated iron (II) hydroxide.

Abstract No. 59

Corrosion Inhibition and Electronic Configuration at the Amino Nitrogen Atom

Norman Hackerman, Dept. of Chemistry, University of Texas, Austin 12, Texas, and **R. R. Annand** and **R. M. Hurd,** Texas Research Associates, Austin, Texas

The effect of varying the electron density around the amino nitrogen atom on the efficiency of the amines as inhibitors for mild steel in air-free, acid solutions for a series of *para* substituted N-methylanilines is discussed. Estimates of relative electron densities were made from measurements of base strengths and shifts in the absorption spectra. Base strengths and relative strains in a homologous series of polymethylene imines have also been compared to inhibitor efficiencies. Explanation of these effects is given in terms of the type of bond formed between the amino nitrogen and the metal substrate.

Abstract No. 60

Capacitance Studies on Corroding Metal Electrodes

H. M. Joseph and **R. A. Powers,** Research Lab., Union Carbide Consumer Products Co., Parma, Ohio

Behavior associated with the electrical double layer at metal surfaces immersed in concentrated electrolytes has been investigated. Large capacitance values observed are "pseudocapacities" arising from reversible metal-metal ion equilibria rather than true double layer capacities. Certain limited, but apparently real, relationships have been noted between observed "pseudocapacity" and corrosion phenomena under the same conditions. Under ideal conditions, capacitance data may be used to estimate corrosion rates and degree of corrosion inhibition as well as to indicate mechanisms of inhibition. Illustrative data are presented for zinc in NH_4Cl and KOH solutions.

Abstract No. 61

Hydrogen Pickup in Various Zirconium Alloys during Corrosion Exposure in High-Temperature Water and Steam

Stanley Kass, Bettis Atomic Power Div., Westinghouse Electric Corp., Pittsburgh, Pa.

The hydrogen pickup during corrosion in high-temperature water and steam of various binary and ternary alloys of zirconium with iron and tin has been studied. The total hydrogen content of specimens exposed to 750°F steam was found to be greater than that of specimens exposed to 680°F water. Furthermore, the per cent of theoretical hydrogen absorbed in the various alloys was markedly affected by the binary or

ternary alloy addition. The per cent theoretical hydrogen absorbed by binary zirconium-iron alloys increased as the iron content was increased from 0.3 to 1.5 w/o and the value for zirconium-tin alloys increased slightly as tin was increased from 0.5 to 0.9 w/o. The hydrogen pickup behavior of ternary zirconium-tin-iron alloys reflected the behavior of zirconium-iron binary alloys.

Abstract No. 62

Kinetics of Sulfidization of Copper by Hydrogen Sulfide

Andrew Dravnieks, R&D Dept., Whiting Research Lab., Standard Oil Co. (Indiana), P. O. Box 431, Whiting, Ind.

The formation of cuprous sulfide scale on copper in hydrogen sulfide at 90°-250°C follows a novel scale-growth law: thin scale grows slowly, but the rate accelerates toward a limiting value as the scale thickens. The kinetics of the sulfidization of wires, Tubandt-Wagner-diffusion experiments, and *in situ* observations on growing scales indicate that the rate is controlled by a slow surface reaction occurring on exposed and inner surfaces of porous scale.

Abstract No. 63

Copper Sulfide Creep on Porous Electroplate

M. S. Frant, Research Div., AMP Inc., Harrisburg, Pa.

Creepage of copper sulfide out from pore sites on tin electroplate on copper has been found in samples returned from field use. Similar creepage has been observed in the laboratory for tin plate on copper and copper-silver alloy, for nickel and for gold on copper, for electroless palladium over nickel and brass, and for lacquered copper specimens. Moisture accelerates the growth of sulfide films in sulfur vapor at 60°.

Abstract No. 64

Anode Polarization Effects

O. L. Riggs, Jr., J. D. Sudbury, and **D. A. Shock,** Continental Oil Co., Ponca City, Okla.

Results were presented of an investigation of the polarization of steel and stainless steel anodes. The effect of halogen ions and temperature on the energy required to establish, maintain, and remove passivity was shown. Stress-corrosion cracking experiments were conducted to determine the effect of anodic currents on the tendency of stainless steel to crack. Several experiments were carried out to better define the nature of the passive layer. These include measurements of the impedance of the film, electron microscope studies, and a summary of properties usually considered in characterizing semiconductors. Emphasis was made on the relation between impedance of the anode and the throwing power of the electrochemical cell.

Abstract No. 65

Anodic Behavior of Austenitic Stainless Steels and Susceptibility to Stress Corrosion Cracking

S. Barnartt and **D. van Rooyen,** Research Labs, Westinghouse Electric Corp., Pittsburgh 35, Pa.

The corrosion in boiling 42% $MgCl_2$ of a purified 16 Cr-20 Ni stainless steel was compared with that of a commercial 18 Cr-8 Ni alloy. Potential-time curves were compared with those of the pure metals Fe, Cr, and Ni, and the effect of stress and other variables determined. A potentiostatic method was used to follow corrosion currents at elevated potentials and to obtain potential-current curves. Cracking of the 18-8 alloy was greatly accelerated by HCl addition and by a relatively small rise in potential, through elimination of the crack-initiation period. The purified 16-20 steel was unsusceptible to stress corrosion cracking, even under conditions of relatively rapid anodic dissolution. Results were consistent with a purely electrochemical mechanism of crack propagation.

Abstract No. 66

The Volatilization of Chromium Oxide

D. Caplan and **M. Cohen,** Div. of Applied Chemistry, National Research Council, Ottawa, Ont., Canada

The phenomenon of evaporation of chromium oxide from chromium alloys oxidized at high temperatures was investigated by observing the loss in weight when Cr_2O_3 pellets were heated at 1000°-1200°C in various atmospheres. Appreciable volatilization occurred in oxygen, more in wet oxygen, but none in argon or wet argon. Fe_2O_3 specimens showed volatilization in none of these atmospheres. The results indicate that evaporation occurs by oxidation of Cr_2O_3 to gaseous CrO_3.

Abstract No. 67

The Passivity of Austenitic Stainless Steels in Sulfuric Acid

N. D. Greene, Metals Research Labs., Union Carbide Metals Co., Niagara Falls, N. Y. (Present address: Dept. of Metallurgical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.)

A potentiostatic anodic polarization technique was utilized in an electrochemical study of the passivity of several austenitic stainless steels. The influence of alloy composition, acid concentration, and temperature on active-passive transition characteristics was determined. Eighteen per cent chromium-8% nickel stainless steel exhibited four passive regions in sulfuric acid, and two of these regions were found to be important factors in its corrosion resistance. Active-passive transitions and passive dissolution rates were observed to be markedly time-dependent. The usefulness of potentiostatic polarization techniques as a method for predicting corrosion behavior was demonstrated.

Abstract No. 68

Effect of Oxygen on the Active-Passive Behavior of Stainless Steel

N. D. Greene, Metals Research Lab., Union Carbide Metals Co., Niagara Falls, N. Y. (Present address: Dept. of Metallurgical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.)

Potentiostatic anodic polarization techniques were used to determine whether dissolved oxygen has any effect on the active-passive behavior of Type 430 stainless steel. Oxygen does not affect the anodic dissolution kinetics of this alloy significantly. This result is contrary to adsorbed oxygen theories of passivity.

Abstract No. 69

Kinetics of Redox Reactions on Passive Electrodes

A. C. Makrides, Metals Research Labs., Union Carbide Metals Co., Niagara Falls, N. Y.

Anodic and cathodic overpotentials for redox reactions on passive electrodes follow Tafel's relation. Exchange current densities are smaller and both Tafel coefficients larger than generally found on active electrodes. A detailed study of redox reactions on a passive iron-chromium alloy is reported, and an attempt is made to account for the Tafel coefficients, kinetic order, temperature dependence, and salt effects observed.

Abstract No. 70

Critical *p*H and Critical Current Density for Passivity in Metals

H. H. Uhlig, Corrosion Lab., Dept. of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

Equations are derived for the relation of Flade potential to critical *p*H for passivity, and for critical current density as a function of H^+. For metals passivated by O_2, e.g. Fe, the critical *p*H is proportional to the negative logarithm of O_2 concentration. For metals passivated by acids, e.g. Mo, Ti, Ta, Zr, the Flade potential must be more active than the hydrogen electrode potential in the same solution, and critical *p*H is lower the smaller the value of H_2 overvoltage.

Abstract No. 71

Anodic Polarization and Passivity of Ni and Ni-Cu Alloys in Sulfuric Acid

J. Osterwald and **H. H. Uhlig,** Corrosion Lab., Dept. of Metallurgy, Massachusetts Institute of Technology, Cambridge 39, Mass.

Potentiostatic anodic polarization curves were obtained for Ni, Cu, and Ni-Cu alloys in 1*N* H_2SO_4. Critical current density for passivity increases with Cu content

as does current required to maintain passivity. Characteristics of passivity in alloys disappear below 30% Ni. The potential of Ni corresponding to critical current density for passivity approximates the most active critical potential in self-activation curves and is linear with *p*H. The results are related to structure of the passive film and interpreted on thermodynamic grounds.

Abstract No. 72

Corrosion Behavior and Passivity of Nickel-Chromium and Cobalt-Chromium Alloys

A. P. Bond and **H. H. Uhlig,** Corrosion Lab., Dept. of Metallurgy, Massachusetts Institute of Technology, Cambridge 39, Mass.

Pure Ni-Cr alloys containing up to 29% Cr and Co-Cr alloys containing up to 23% Cr were prepared in vacuum. Corrosion rates in sulfuric and nitric acids, corrosion potentials, and critical current densities for passivity were determined at 25°C. The critical minimum Cr content for passivity depended on the environment. It is concluded that specific alloying proportions of passive compositions are better evaluated in relation to electron configuration of the alloy system by critical current densities than by potential or corrosion rate measurements.

Abstract No. 73

Relation of Electron Configuration to Passivity in Cr-Ni-Fe Alloys

H. G. Feller and **H. H. Uhlig,** Corrosion Lab., Dept. of Metallurgy, Massachusetts Institute of Technology, Cambridge 39, Mass.

Critical current densities for passivity, and Flade potentials were measured for ternary Cr-Ni-Fe alloys. Two discontinuities of slope for critical current plotted with % Cr are found for the 50% and 60% Ni alloy series. These occur close to the ratio 12/88 for Cr to Fe, and 14/86 for Cr to Ni as found in the binary systems. The results are interpreted in terms of separate electron interaction in the ternary system between Cr and Fe distinct from interaction between Cr and Ni.

Abstract No. 74

Formation and Breakdown of Passive Films on Iron Single Crystal Surfaces

Jerome Kruger, National Bureau of Standards, Washington 25, D. C.

The thickness of films found on pure ion surfaces immersed in concentrated HNO_3, chromate and nitrite solutions was studied using the ellipsometer. Potential measurements made at the same time as ellipsometric measurements indicate that a film of 15-30Å is respon-

sible for passivity. A logarithmic rate law was found to govern film formation in the passivating solutions. Optical and electron microscopy studies using a decoration technique revealed the influence of crystallographic orientation on film breakdown processes.

Abstract No. 75

Anodic Polarization Behavior of Iron-Nickel Alloys in Sulfuric Acid Solutions

George Economy, (present address: Aluminum Co. of America, New Kensington, Pa.) **Rudolph Speiser, F. H. Beck,** and **M. G. Fontana,** Dept. of Metallurgical Engineering, Ohio State University, Columbus, Ohio

The anodic behavior of twelve annealed iron-nickel alloys in hydrogen saturated H_2SO_4 solutions at 25° ±1°C was investigated by galvanostatic and potentiostatic techniques. The anodic behavior was correlated with the metallurgical structure and electrochemical environment. Particular emphasis was placed on the interpretation of corrosion potential, passivation current, passive current, and the passive-active transition. All the alloys became passive at noble potentials. In general the behavior of the alloys was intermediate to the behavior of iron and nickel.

Abstract No. 76

Factors Influencing the Rates of Surface Processes

A. C. Riddiford, Dept. of Chemistry, University of Southhampton, U. K.

In common with other branches of science, our knowledge of the general field of surface phenomena has developed through the study of at first sight seemingly diverse topics. The fascination and difficulty of such studies stem directly from the number of variables with which workers in any given field may have to contend. In the case of a simple model corrosion system, for example, there are at least ten factors which may influence the observed rate. Nevertheless, progress is now so rapid as to render periodic general surveys of these factors both desirable and practicable.

Abstract No. 77

Dissolution of Copper in Sulfuric Acid Solutions

D. P. Gregory and **A. C. Riddiford,** Dept. of Chemistry, University of Southhampton, U. K.

When copper disks rotate in sulfuric acid solutions, the observed rate of dissolution is first order with respect to the concentration of dichromate ion used as a depolarizer. By studying the effect of temperature and stirring speed at high and low acid concentrations, the process is shown to be completely determined by the rate of transport of dichromate ion to the reacting surface. This has been confirmed by studying the effect of different surface preparations, by measuring the rate of reaction of other metals with these solutions, and by comparing the observed rates with the theoretical

values. The effect of blocking off progressively larger areas of the working surface is reported.

Abstract No. 78

Kinetics of the Reaction between Copper and Aqueous Ammonia

J. S. Stanley and **J. A. Radley**, Industrial Research and Development Labs., 220-222 Elgar Rd., Reading, Berks., U. K.

Copper reacts with aqueous ammonia in the presence of oxygen as follows:
$Cu + \frac{1}{2} O_2 + 4NH_3\ (aq) + H_2O \rightarrow Cu(NH_3)_4^{++} + 2\ OH^-$
The kinetics of this reaction were studied by varying the concentration of ammonia, the partial pressure of oxygen, and the stirring velocity over wide ranges. The rate-determining step is diffusion of one of the reactants to the metal surface, and the course of the reaction depends on the relative concentrations of oxygen, cuprammonium ion, and ammonia in the solution. When cuprammonium ions are reduced by metallic copper, the rate is determined by the transport of the cuprammonium ions to the metal surface.

Abstract No. 79

Dissolution of Copper in Ferric Chloride Solutions

H. M. Ferrari, Metallurgical Advisor, Euratom, Paris, France, and **M. J. Sinnott,** Dept. of Metallurgical Engineering, University of Michigan, Ann Arbor, Mich.

The kinetics of the dissolution of copper in ferric chloride solutions has been studied as a function of the solution and metallic variables. The rate of dissolution of copper single crystals as a function of the ferric chloride concentration; ion contents of chloride, ferric, cupric, ferrous and hydrogen; dissolved oxygen content; and metallic variables of crystallographic orientation and surface finish were studied. Mechanisms which describe the reactions in terms of the kinetic data are presented.

Abstract No. 80

Characteristics of the {111} Surfaces of the III-V Intermetallic Compounds, III. Effect of Cold Work on Dissolution

H. C. Gatos and **M. C. Lavine,** Lincoln Lab., Massachusetts Institute of Technology, Lexington, Mass.

The dissolution rate of the {111} surfaces of the III-V intermetallic compounds increases sharply as a result of surface damage introduced by abrasion. This increase in rate is employed for determining the depth of surface damage. In the present case the observed increase in rate is not due to the higher reactivity of the cold worked surface since the dissolution processes studied are under diffusion control. The experimental results are interpreted on the basis of the surface roughness as affected by the presence of cold work.

Abstract No. 81

A Simple Method for Monitoring the Chemical Etching Rate of Germanium and Silicon

D. R. Turner, Bell Telephone Labs., Inc., Murray Hill, N. J.

The excess holes and electrons produced at the surface of germanium or silicon during chemical etching can be used to monitor the dissolution rate. When an n-type semiconductor electrode is biased anodically or a p-type electrode is made the cathode of an electrolytic cell in the etching solution, the saturation current density is proportional to the rate of etching the semiconductor. The technique also provides a convenient means of determining the fluoride ion concentration in HNO_3-HF mixtures.

Abstract No. 82

Chemical Etching of Germanium, I. Comparison of the Etching of Germanium and Silicon in Solutions of HF-HNO_3

B. Schwartz and **H. Robbins,** Semiconductor Div., Hughes Aircraft Co., P. O. Box 278, Newport Beach, Calif.

The kinetics of the dissolution of germanium and silicon in solutions of nitric acid and hydrofluoric acid is discussed. The etching of germanium is in general more difficult than that of silicon. The etch rates of the latter are reproducible and constant in time, whereas the etch rates of germanium are extremely erratic. In addition, the etch rates of silicon are independent of crystallographic orientation, whereas those of germanium are strongly affected by the crystal orientation over large ranges of composition of etchant. There are also significant differences between the two elements in the temperature dependence of the etch rates.

Abstract No. 83

Chemical Etching of Germanium, II. The System HF, H_2O_2, H_2O

H. Robbins and **B. Schwartz,** Semiconductor Div., Hughes Aircraft Co., P. O. Box 278, Newport Beach, Calif.

The kinetics of the reaction of germanium with solutions of HF and H_2O_2 has been investigated as a function of the composition and temperature of the etchant. The effect of conductivity type and surface orientation on the kinetics has been studied. At low weight ratios of HF to H_2O_2 the etch rates are linearly dependent on the HF concentration, and at high ratios the rates are linearly dependent on the H_2O_2 concentration. The activation energy goes through a maximum at a composition of about 1 H_2O_2 to 1 HF.

Abstract No. 84

Steady-State Liquid-Solid Interface Reactions as Applied to Silicon Etching by HNO_3-HF-H_2O

J. J. Grossman, Semiconductor Div., Hughes Products, Hughes Aircraft Co., P. O. Box 278, Newport Beach, Calif.

Phenomenological equations for steady-state etching of silicon surfaces by diffusion across a bounding liquid film are written using the known homogeneous phase reaction mechanism of HNO_3 with HNO_2, NO_2, and NO. Minimal sets of measurements required to define, unambiguously, the solid-liquid interface reaction are discussed including contributions from semiconductor properties and oxide films. Finally it is shown that activation energies measured in terms of bulk solution concentrations can be misleading.

Abstract No. 85

Magnitude of *IR*-drop Corrections in Electrode Polarization Measurements Made with a Luggin-Haber Capillary

Sidney Barnartt, Research Labs., Westinghouse Electric Corp., Pittsburgh 35, Pa.

Measurement of electrode polarization by the direct method, using a Luggin-Haber capillary, may involve errors resulting from shielding of the electrode surface and from the *IR* drop included in the measurement. When shielding errors are eliminated, accurate corrections for the *IR* drops are readily calculated for planar electrodes. The magnitudes of these corrections are presented. The assumption involved in making similar calculations for cylindrical and spherical electrodes, and the effect of electrode radius on the magnitude of the *IR* drops, are discussed.

Abstract No. 85A

Inhibition of the Corrosion of Pure Aluminum in Hydrochloric Acid Solutions

J. Sundararajan and **T. L. Rama Char,** Electrochemistry Lab., Dept. of Inorganic and Physical Chemistry, Indian Institute of Science, Bangalore, India

The corrosion rates for 99.5% aluminum have been determined in HCl solutions. Inhibitor efficiencies have been calculated for the following substances, the efficiency decreasing in the order: acridine, thiourea, nicotinic acid, tannic acid, dextrin. Dissolution of the metal is electrochemical in character. Polarization studies with thiourea show that anode polarization is negligible, whereas cathode polarization is considerable. The corrosion process with this inhibitor appears to be essentially under cathodic control.

Abstract No. 86

(There is no Abstract No. 86)

Abstract No. 87

(There is no Abstract No. 87)

Abstract No. 88

(There is no Abstract No. 88)

ELECTRODEPOSITION

Abstract No. 89

Chemical Deposition of Palladium and Other Platinum Metals

R. N. Rhoda, Research Lab., International Nickel Co., Inc., Bayonne, N. J.

Ductile and adherent palladium may now be deposited reproducibly on a number of catalytic surfaces with ease. The development of this process is reviewed and recent work involving operating conditions and stabilizing of baths is discussed. Advantages of this method as weighed against its present limitations indicate early commercial adoption. Attempts to extend this method to other platinum metals are discussed briefly.

Abstract No. 90

'Electroless' Deposition of Gold from Aqueous Solution on Base Metals of Nickel, Iron-Nickel-Cobalt Alloys, and Gold

R. F. Walton, Glass to Metal Seals Dept., Semiconductor-Components Div., Texas Instruments, Inc., Dallas, Texas

A new solution formulation for the chemical (electroless) deposition of gold is proposed. The main constituents of this solution are potassium gold cyanide, citric acid or tartaric acid, tungstic acid, and N, N-diethylglycine sodium salt. Optimum concentrations of these constituents were determined by a statistical evaluation of the solution at four concentration levels. Investigation of such variables as immersion time, solution temperature, and *p*H, which affect the chemical deposition of gold from solution, enabled determination of the optimum operating conditions.

Abstract No. 91

Chemical Plating with Borohydrides

E. A. Sullivan, Research and Development Labs., Metal Hydrides Inc., Beverly, Mass.

Essentially pure nickel and cobalt have been plated on both metals and nonmetals by chemical deposition with borohydrides. The aqueous plating baths are maintained strongly alkaline (*p*H~12) to prevent the usual formation of transition metal borides. Deposition

is initiated by warming the baths to 40°-50°C. Smooth, adherent, continuous plates of nickel and cobalt have been formed by this method, particularly on non-metals such as ceramics, plastics, and glass.

Abstract No. 92

An Electroless Copper Plating System for 'Pure' Aluminum

S. L. Matlow, Hoffman Electronics Corp., 1001 Arden Drive, El Monte, Calif.

A method has been found for displacement plating copper onto "pure" aluminum. The aluminum is first cleaned in perchlorethylene and NaOH baths, then given a sensitizing dip in acidic $CuCl_2$. The plating, done in an ammoniacal solution of $CuCl_2$, adheres quite well and is self-fluxing on soldering. The solder bond formed by this process is found to be stronger than the aluminum itself as determined by soldering two B&S gauge No. 14 aluminum wires together with a ¼ in. overlap. When placed under tension, the solder-copper and the copper-aluminum bonds do not fail; the wire breaks instead.

Abstract No. 93

Mechanisms of Electroless Deposition of Metals on Silicon

S. L. Matlow, Hoffman Electronics Corp., 1001 Arden Drive, El Monte, Calif.

Studies on the electroless deposition of metals onto silicon indicate that there are at least four independent mechanisms by which the deposition can occur. These are (*a*) displacement plating, (*b*) displacement-replacement plating, (*c*) autocatalytic, homogeneous, and (*d*) autocatalytic-heterogeneous. These mechanisms can be distinguished by the apparent rate laws which are obeyed and by the nature of the metallic deposit. Examples of each case are discussed. Except for case (*c*) details of the mechanisms and the experimental data on which they are based are discussed.

Abstract No. 94

Immersion Coatings of the Platinum Metals

R. W. Johnson, Precious Metals Research Lab., Mond Nickel Co., Ltd., Thameshouse, Millbank, London, S.W. 1, England

(No abstract received)

Abstract No. 95

Impedance Phenomena in Molten Salts

G. J. Hills and **K. E. Johnson** (present address: University of Illinois, 314 Noyes Lab., Urbana, Ill.), Dept. of Chemistry, Imperial College, London S.W. 7, England

Impedances at polarized platinum microelectrodes in various molten salt systems (LiCl-KCl, NaBr-$AlBr_3$, $PbCl_2$, and $NaNO_3$-KNO_3) have been measured. A frequency dispersion of both resistance and capacitance was observed in all cases, but apparent double layer capacities obtained by extrapolation to infinite frequency were in agreement with some previously reported data, and of magnitudes consistent with a simple Helmholtz model. The potential dependence of capacity for NaBr-$AlBr_3$ eutectic at 225°C was also consistent with this model but that for LiCl-KCl eutectic at 400°C could only be interpreted in terms of the specific adsorption of chloride ions.

Abstract No. 96

Electrolytic Metallide Coatings in Molten Fluoride

N. C. Cook, Research Lab., General Electric Co., Schenectady, N. Y.

(No abstract received)

Abstract No. 97

Electrophoretic Deposition of Oxidation-Resistant Coatings on Molybdenum and Solid Lubricant Coatings on 304 Stainless Steel

P. F. Campbell, K. A. Gebler, and **S. J. Klack,** Vitro Labs., Div. of Vitro Corp. of America, 200 Pleasant Valley Way, West Orange, N. J.

Molybdenum disilicide-6% nickel coatings were electrophoretically deposited on molybdenum test coupons and molybdenum-0.5% titanium alloy tensile specimens. The coupons resisted oxidation in static air at temperatures up to 2600°F. The tensile specimens were thermally cycled under load at 1800°F for 67 hr before failure. Failures of the coatings at 1800°F is attributed to poor ductility, and a program is described for improving the ductility. A test apparatus is described, and results are given for the evaluation of solid lubricants, electrophoretically deposited and diffusion bonded to 304 stainless steel.

Abstract No. 98

Electrophoretic Deposition: A Versatile Coating Method

C. P. Gutierrez, J. R. Mosley, and **T. C. Wallace,** University of California, Los Alamos Scientific Lab., Los Alamos, N. M.

The technique of electrophoretic deposition has been investigated as a method for the formation of coats of various metals, oxides, carbides, and metal plus oxide composites. Comminution of powders for optimum particle size distribution and the choice of suspension medium are discussed. The importance of purity in all components is stressed in the preparation

of stable suspensions with satisfactory plating characteristics. The deposition of the following materials is described in detail as examples of the versatility of the electrophoretic coating method: Re, Zr, Nb, Mo, UO_2, Nb-UO_2, Mo-UO_2, and ZrC-UC.

Abstract No. 99

Electrophoretic Deposition of Aluminum

F. Pearlstein, R. Wick, and **A. Gallaccio,** U. S. Army Ordnance, Frankford, Arsenal, Philadelphia 37, Pa.

Suspensions of aluminum flake in various organic solvents were prepared from which electrophoretic deposits were made. The best results were obtained from stable metal suspensions in acetone, chloroform, or methyl acetate. Additives were found to be effective for improving suspension stability, electrophoretic deposition rates, deposit cohesion, and throwing power. Preliminary work on the diffusion of electrophoretic deposits on steel is described.

Abstract No. 100

The Electrodeposition of Cermets

J. C. Withers, Chemistry Dept., American and Foundry Co., 1025 N. Royal St., Alexandria, Va.

Cermets can be electrodeposited by suspension of the ceramic particles in a conventional electroplating bath. The amount of ceramic codeposited is strongly dependent on the ceramic particle size, method of suspension, and the cathode current density. Cermets of chromium, nickel, cobalt, tungsten, platinum, and rhodium with Al_2O_3, $MoSi_2$, ZrO_2, and SiO_2 have been prepared for use as high-temperature materials such as coating and structural bodies.

Abstract No. 101

Effect of Organic Compounds on the Codeposition of Hydrogen with Nickel

J. R. Goodwyn (present address: Texas Eastman Co., Longview, Texas) and **T. C. Franklin,** Chemistry Dept., Baylor University, Waco, Texas

The codeposition of hydrogen with nickel has been studied in a Watts bath to which various organic compounds were added. Using a coulometric method to measure the amount of hydrogen codeposited, it has been shown that generally the concentration of additive which produced the brightest deposit also produced the deposit containing the least amount of hydrogen. A possible explanation for the curves relating the hydrogen content and the additive concentration is provided by electrode potential data.

Abstract No. 102

Mechanism of Addition Agent Reaction in Bright Nickel Deposition

S. E. Beacom and **B. J. Riley,** Research Labs., General Motors Corp., 12 Mile and Round Rds., Warren, Mich.

Organic addition agents synthesized with C-14 as well as S-35 have been used in a continuing study of the leveling phenomenon associated with the deposition of bright nickel. Analysis of deposits and the gaseous products of deposition have led to speculations concerning the breakdown of addition agents and the possible interactions which may account for the synergistic effect on leveling brought about by combinations of addition agents. Studies have shown that the amount of breakdown products is related to current density and polarization.

Abstract No. 103

Electrodeposition of Iridium

E. L. MacNamara, Pitman-Dunn Labs., U. S. Army Ordnance Arsenal, Frankford, Philadelphia 37, Pa.

The requirement of high-temperature stable protective coatings in certain military applications has focused attention on the Platinum Group Metals. The properties of iridium are of particular interest. Procedures for the aqueous deposition of rhodium, palladium, and platinum are fairly well established. The only successful method reported for the deposition of iridium utilizes molten salts. Experiments at this laboratory have demonstrated that iridium can be plated from aqueous solution containing quadrivalent iridium. Bright, tenacious deposits are obtained with a cathode efficiency of 12% at these optimum conditions; metal content, 10 g/l; current density, 20 amp/ft^2; temperature, 60°C.

Abstract No. 104

Electrodeposition of Pure Copper

Sidney Barnartt, Research Labs., Westinghouse Electric Corp., Pittsburgh 35, Pa.

Previous methods of purifying copper by electrodeposition have involved alternate electroplating and melting steps. A highly simplified procedure consisting of electrodeposition from an acid sulfate solution pretreated with sodium sulfide is described. Analytical data and residual resistivity measurements at liquid helium temperatures are presented.

Abstract No. 105

Electrodeposition of High-Purity Chromium from Electrolytes Containing Fluoride or Fluosilicate

N. E. Ryan, Aeronautical Research Labs., Australian Defence Scientific Service, Dept. of Supply, Melbourne, Australia

Investigation of the variables affecting the laboratory scale deposition of chromium from chromic acid electrolytes containing fluoride or fluosilicate has enabled the optimum conditions for the production of high purity chromium (0.03-0.04 wt% oxygen, 0.0008-0.0002 wt% nitrogen) at the highest current efficiency (38-45%) to be determined. This current efficiency is much higher than the 8-10% in the chromic acid-sulfate electrolyte in which chromium of a similar grade can be produced. Continuous electrodeposition in a larger cell showed that the current efficiency in fluoride-containing electrolytes decreased progressively with time to a steady 25-30%. No explanation has been found for this decrease. After steady conditions have been achieved the advantages in current efficiency of the fluoride over the sulfate bath remains substantial.

Abstract No. 106

Measurement of Stress in Very Thin Electrodeposits

H. Watkins and **A. J. Kolk,** Electronics Div., National Cash Register Co., Hawthorne, Calif.

A modified form of the Brenner-Senderoff contractometer is described. Greater sensitivity is achieved by using jewel bearings and optical read-out. The sensitivity is sufficient to determine a 10 KSI stress in a 200Å film. This instrument has been used to study the initial growth of the plating in thin electrodeposited films of iron-nickel alloys. Electron micrographs of the films were made to help in interpreting the stress data.

Abstract No. 107

Influence of Thiourea on the Deposition of Iron-Nickel Films

R. D. DeMars, IBM, Research Center, Poughkeepsie Lab., P. O. Box 390, Poughkeepsie, N. Y.

The deposition reactions of iron and nickel were studied polarographically in solutions containing the metal ion and potassium chloride and the metal ion, potassium chloride and thiourea. Analysis of the polarographic waves using Koutecky's method yielded values for the kinetic parameters, αn_a and $k^\circ_{f,b}$, for the reduction reactions. The affect of temperature and thiourea concentration on these parameters was studied. These results can lead to predictions about the composition of films plated from similar solutions. The predictions are substantiated by a series of plated iron-nickel films.

Abstract No. 108

Influence of Substrates on Thin Magnetic Films Electrodeposited in a Magnetic Field

M. Lauriente and **F. X. McNally,** Air Arm Div., Westinghouse Electric Corp., Baltimore 3, Md.

An investigation was made of the influence that various substrates have on the magnetic properties of thin magnetic films of nominal composition 80Ni-20Fe, electrodeposited in a magnetic field. Included in the study were chemically reduced silver, copper-clad laminate, and sputtered, vacuum evaporated and fired gold. Electron micrographs and magnetic measurements were used to explain some of the unusual magnetic characteristics which were found.

Abstract No. 109

Electrodeposition of Cobalt-Molybdenum Alloys

Albertine Krohn and **T. M. Brown,** University of Toledo, Toledo, Ohio

Previous studies showed that iron-molybdenum alloys could be deposited from pyrophosphate solutions. This investigation shows that a similar bath can be used to deposit cobalt-molybdenum alloys. The addition of hydrazine sulfate to the plating bath prevents anodic oxidation of Co(II) to Co(III). It also causes an increase in the cathode current efficiency and an increase in the molybdenum content of the deposits. Efficiency is further increased by wiping the cathode during plating.

Abstract No. 110

Composition and Thickness Effects on Magnetic Properties of Electrodeposited Thin Nickel-Iron Films

Irving Wolf, Electronics Lab., General Electric Co., P. O. Box 1122, Syracuse, N. Y.

Thin films of nickel-iron have found use in the fabrication of magnetic memories for information storage in computers. These memories have the advantage of very high speed switching. Use is made of a magnetic field during deposition to align the magnetic axes in the film in one direction so that the film exhibits a single "easy" axis of magnetization. Thus an "induced" anisotropy is established. In this work, effects of thickness (500-6000Å) and composition (~60%Ni-100% Ni) on the anisotropy field, H_k, as well as on wall coercive force, H_c, and easy direction disturb, H_c, are presented. Evidence for stress interaction with magnetization and some data on substrate roughness are given.

Abstract No. 111

Effect of Plating Parameters on the Structure and Magnetic Properties of Co and Co-Ni Alloys

I. M. Croll and **H. F. Quinn,** IBM Federal System Div., Owego, N. Y.

Electrodeposited Co and Co-Ni alloys have been prepared under a wide range of plating conditions in an attempt to correlate specific bath conditions with grain orientation, grain size, and microstrain in the

deposits. Striking changes in the texture of deposits prepared from simple baths have been found to occur in a critical *p*H region (3.5-4.0). Extreme preferred orientation has been obtained in deposits plated under combination a-c and d-c conditions. Specific ferromagnetic properties of the deposits are correlated with their structure.

Abstract No. 112

Electrodeposition of Nickel-Cobalt Alloys from the Pyrophosphate Bath

Vasanta Sree and **T. L. Rama Char,** Electrochemistry Lab., Dept. of Inorganic and Physical Chemistry, Indian Institute of Science, Bangalore, India

Nickel has been codeposited with cobalt from the pyrophosphate bath. Detailed studies on alloy composition, cathode efficiency, and potential have led to the optimum conditions for obtaining satisfactory alloy plates with 10-91% nickel. The efficiency of cast alloy anodes is quite high. X-ray patterns of the deposits show the existence of fcc and hexagonal structures. The deposit composition could be altered appreciably only by varying the metal content of the bath.

Abstract No. 113

Electrical Behavior of Passive Iron

J. L. Ord and **J. H. Bartlett,** University of Illinois, Urbana, Ill.

Make and break transients have been recorded for passive iron anodes in sulfuric acid. Capacitative effects are very important, especially when the steady state has been interrupted and the initial part of the open-circuit potential decay curve is examined. To a good approximation, the iron anode may then be represented by an equivalent circuit consisting of a large capacity shunted by a steep Tafel element. On the second portion of the decay curve, the potential decreases in an approximately linear fashion for about 100 mv to a value (Flade potential) where activation ensues.

Abstract No. 114

Anodic Properties of Nickel under Nonpassivating Conditions

Marvin Kronenberg (present address; Union Carbide Research Center, Parma, Ohio), **Ernest Yeager,** and **Frank Hovorka,** Dept. of Chemistry, Western Reserve University, Cleveland, Ohio.

Anodic polarization measurements have been made on single crystal and polycrystal nickel in aqueous chloride, perchlorate, and sulfate solutions under nonpassivating conditions with an electronic commutator. In the presence of a large excess of a neutral salt, the activation polarization has been found to be strongly

dependent on the type of anion but substantially independent of the *p*H, concentration of nickel ions, and macro orientation of the electrode surface. Energies of activation have been evaluated from the temperature dependence.

Abstract No. 115

Effect of Cathode Vibration on Overpotential of Lead in $NaHPbO_2$ and in Alkaline Lead Tartrate Solutions

J. L. Griffin, Research Labs., General Motors Corp., Warren, Mich., and **L. O. Case,** University of Michigan, Ann Arbor, Mich.

Tartrate ion concentration and *p*H have marked, opposing effects on the overpotential at a lead cathode in alkaline lead tartrate solutions. Vibrating the lead cathode normal to its surface at 8 kc/sec generally reduced overpotentials by a greater magnitude than that calculated from the relation,

$$E_c = 2.303 \frac{RT}{z\mathbf{F}} \ln \frac{{}^{i}L - {}^{i}}{{}^{i}L}$$

at apparent current densities less than limiting. Depolarization by vibration of the cathode was not complete at currents less than limiting.

Abstract No. 116

Some Observations of Copper Deposits on Single Crystals of Copper

I. B. Giron (Guest Worker from Lima, Peru) and **Fielding Ogburn,** National Bureau of Standards, Washington, D. C.

Isolated faces of copper single crystals were plated with copper from sulfuric acid-copper sulfate solutions. Metal distribution and topography of the deposits were observed, cross sections were examined microscopically, and x-ray diffraction patterns were obtained. Topography was characteristic of crystallographic plane. Deposits giving diffraction patterns showing uniform orientation were found to contain grain boundaries associated with topographic features. Over-all metal distribution showed a tendency to deviate from normal current distribution toward establishment of a more closely packed plane.

Abstract No. 117

Electroplating of Silver onto Aluminum

V. A. Nelson, Research Labs., Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

A method for plating silver onto aluminum by means of a mercury immersion coating has been developed and can be used with conventional plating equipment. Corrosion, mechanical, and electrical tests show that the resulting plates are of comparative quality to pres-

ent commercial plates. Aside from conventional cleaning, the new plating procedure requires only two chemical baths and one electrochemical operation. The new plating procedure permits aluminum to be silver-plated even more conveniently than copper.

Abstract No. 118

Porosity Measurements on Gold-Plated Copper

M. S. Frant, Research Div., AMP Inc., Harrisburg, Pa.

Using a chemical porosity test (in which the specimen is exposed to an ammonia-ammonium persulfate solution which attacks copper but not gold, so that the amount of copper dissolved is a measure of the porosity of the coating), the conventional cyanide gold bath and 6 proprietary baths were compared for porosity. The relationship between porosity and thickness was found to be $P = at^{-n}$, where P is chemical porosity, a varies for each bath, t is gold thickness, and n generally varies between 1.3 and 2. A linear relationship, with a slope close to 1, was found for the variation of porosity with current density in both alkaline and acid baths.

ELECTRODEPOSITION—ELECTROTHERMICS AND METALLURGY

Abstract No. 119

Prepurification Techniques: Their Role in Metal Production

R. G. Bourdeau and **E. Rose,** The Alloyd Corp., 35 Cambridge Pkwy., Cambridge 42, Mass.

The hydrogen reduction of metal halides was investigated as a technique for the production of high-purity tungsten and molybdenum. The approach used relied on the degree of purity which could be achieved in the starting materials. Particular emphasis was placed on zone refining of the metal chlorides as a means of achieving low impurity levels in the metals produced. The techniques developed, as well as the results obtained during this investigation, are presented.

Abstract No. 120

Mass and Heat Transfer during the Vapor Deposition of Metals

J. H. Oxley and **J. M. Blocher, Jr.,** Battelle Memorial Institute, Columbus 1, Ohio

A general mathematical treatment of the mass and heat transfer rates in a de Boer-Van Arkel refining cell is presented. This treatment covers one of the more practical process situations wherein the change in dimensions of the deposition surface, as a result

of metal deposition, significantly affects the diffusion path between the deposit and feed and the heat lost by the deposition surface. A steady-state, counter-diffusion, nonconvective system is assumed.

Abstract No. 121

Mechanism of Hydrogen Reduction of Cuprous Iodide Vapor

C. R. Morelock and **G. W. Sears,** Research Lab., General Electric Co., Schenectady, N. Y.

A study has been made of the growth of copper whiskers by the hydrogen reduction of cuprous iodide vapor. Alternative mechanisms have been proposed involving a homogeneous vapor phase reduction and a surface catalyzed reduction at the whisker tip. A necessary consequence of the homogeneous vapor phase reaction is the existence of a highly supersaturated copper vapor. It is shown that the vapor was not appreciably supersaturated in copper vapor and that the catalytic site is probably the step associated with an axial screw dislocation in the growing whisker.

Abstract No. 122

Tungsten Coatings by Gas Phase Deposition

W. E. Reid, Jr., and **Abner Brenner,** National Bureau of Standards, Washington, D. C.

Thick, dense coatings of tungsten were obtained by passing a mixture of tungsten hexafluoride and hydrogen over an object heated to 650°C. The reaction is heterogeneous and the operating conditions are uncritical over a wide range of temperature, pressure, flow rate, and substrate materials. Plating rates of 1 mil/min have been obtained. The investigation included a study of the variation in the properties of the coating with the operating conditions.

Abstract No. 123

Fluidized-Bed Coating of Uranium Dioxide Powder Particles with Niobium and Other Elements

J. M. Blocher, Jr., N. D. Veigel, J. H. Oxley, V. M. Secrest, and **E. E. Rose,** Battelle Memorial Institute. Columbus 1, Ohio

Conditions have been established for applying uniform coatings of niobium to UO_2 powder particles by the hydrogen reduction of $NbCl_5$ vapor in a fluidized bed of the particles. Particle size has ranged from 40 to 200 μ with coating thicknesses of from 1 to 50 μ. Factors involved in maintaining bed fluidity are discussed and preliminary data are given on the coating of UO_2 particles for pyrolytic carbon, chromium, molybdenum, tungsten, and niobium-vanadium alloys.

Abstract No. 124

Vapor Deposition of Carbon onto Sintered UO_2 Reactor Fuel

E. G. Wintucky and **E. H. Layer,** Battelle Memorial Institute, Columbus 1, Ohio

Strongly adhesive carbon coatings have been vapor deposited onto sintered UO_2 platelets by a process involving the thermal decomposition of methane gas at 1025°C. The vapor deposition is carried out in a nitrogen atmosphere at atmospheric pressure. Although the coatings are relatively thin, they are apparently nonporous as evidenced by the prevention of a UO_2-Zircaloy reaction at 862°C. The coatings are currently being used to prevent this reaction during the gas-pressure bonding of PWR-type fuel plates.

Abstract No. 125

Oxidation Resistant Silicide Coatings for Columbium and Tantalum Alloys

R. Lorenz and **A. B. Michael,** Fansteel Metallurgical Corp., North Chicago, Ill.

Two types of oxidation resistant silicide coatings on substrates of columbium and tantalum alloys were investigated. In one case, a thin layer of the alloy substrate is converted to the silicides of the alloy. For the other coating, a molybdenum-rich layer is vapor deposited on the substrate and converted to molybdenum disilicide. The silicides are formed by vapor phase reactions with silicon tetrachloride and hydrogen. The vapor phase techniques, oxidation resistances, mechanical properties, and structures are discussed.

Abstract No. 126

Diffusion Coatings of Refractory Metals on Steel

R. E. Bessey and **W. M. Kisner,** Ordnance Corps, Springfield Armory, Springfield 1, Mass.

Preliminary results of a study to determine the properties of coatings produced on steel by diffusion of refractory metals are presented. Metallic coatings of W, Ta, Mo, Nb, V, Cr, and Ti were applied by vapor deposition, the plasmarc process, or electrodeposition, and were diffused at temperatures of 900°-1100°C. The apparatus for and the method of application of niobium plate by hydrogen reduction of the pentachloride are described. Results are discussed, and photomicrographs of the diffusion layers are presented.

Abstract No. 127

Industrial Aspects of Vapor-Deposited Coatings

H. W. Schultze, The Alloyd Corp., Cambridge, Mass.

Vapor phase techniques are being investigated and utilized more widely because of recent advances in

the technology and ready availability of plating compounds. Fluorides, chlorides, carbonyls and organometallics are making possible the coating of missiles components, electronic parts, nuclear fuel materials, automotive parts, and other products requiring wear resistant or high-temperature coatings. Deposition of composite parts, alloys, and semiconductor alloys is opening up new areas of utility and providing new properties for investigation.

Abstract No. 128

Testing of Vapor-Plated Aluminum Films

F. V. Schossberger and **K. D. Franson,** Armour Research Foundation, Illinois Institute of Technology, Technology Center, 10 W. 35 St., Chicago 16, Ill.

An abrasion-resistivity test was developed to study the uniformity and adhesion of vapor-deposited aluminum films. The essential idea of the abrasion resistivity test is the measurement of resistance of the metal film while its thickness is being reduced in a uniform manner. (The variation of resistance with time between two contacts on unmasked areas can be derived for an ideal model, and the effect of a number of possible departures from the ideal can be shown.) Differences in plating and annealing conditions of evaporated films were detected by this test. Experiments were performed to determine the uniformity of platings by using abrasion time as the criterion. Electron micrographs and electron diffraction diagrams were taken of the surface of the annealed metal film and of the surface of the substrate after dissolving the aluminum film. The pitted substrate surface was observed where the aluminum or the aluminum oxides reacted with the silica of the substrate.

ELECTRONICS—SEMICONDUCTORS

Abstract No. 129

Growth Steps on the Surfaces of Germanium, Silicon, and III-V Compound Dendrites

G. R. Booker, Research Labs., Westinghouse Electric Corp., Beulah Rd., Churchill Boro., Pittsburgh 35, Pa.

The methods of optical, interference, and electron microscopy have been used to study the growth steps occurring on the "flat" surfaces of germanium, silicon, and III-V compound dendrites. Variations in height, slope, form, and distribution of the steps have been observed. The role of the steps in increasing the thickness of the dendrites is discussed.

Abstract No. 130

Silicon Dendrite Studies

S. N. Dermatis, Semiconductor Dept., Westinghouse Electric Corp., Youngwood, Pa., and **J. W. Faust, Jr.,**

Research Labs., Westinghouse Electric Corp., Beulah Rd., Churchill Boro., Pittsburgh 35, Pa.

Dendrites of silicon have been grown and evaluated. Some of the problems of growing silicon dendrites are discussed. Pertinent information of growth processes, segregation, and crystal perfection is given.

Abstract No. 131

Investigations of Crystal Perfection of Semiconductor Crystals by X-Ray Diffraction Microscopy

G. H. Schwuttke, General Telephone & Electronics Labs. Inc., Bayside Labs., Bayside, N. Y.

The application of x-ray diffraction microscopy to semiconductor crystals is discussed. This technique has been used successfully to reveal dislocation structures in single crystals. Now its application to detect impurities in the semiconductor lattice is described. Segregation, cluster formation, and precipitated second phases can be revealed in the diffraction image. The sensitivity of this method makes possible, for instance, the detection of oxygen concentrations in silicon as small as $10^{17}/cm^3$.

Abstract No. 132

Germanium Structural Defects—Their Cause and Effect

D. H. Lyon, Semiconductor Product Dept., General Electric Co., Syracuse, N. Y.

Line defects and point defects found in germanium single crystals are discussed. The line defects are dislocations, and the point defects are believed to be a precipitated phase. Etching methods are used to detect each type of defect by the production of characteristic etch pits, called dislocation pits and saucers. Several observations have been made regarding the origin and control of the default during crystal growth as well as possible effects on device performance.

Abstract No. 133

Horizontal Growth of Germanium Single Crystals Using a Silicon Nitride Receptacle

J. L. Porter, Sylvania Electric Products Inc., Woburn, Mass.

The use of silicon nitride as a replacement for quartz in the horizontal formation of germanium single crystals is described. The complete nonwettability of the silicon nitride offers a distinct advantage and thus facilitates the formation of large cross-sectional ingots of high crystallographic perfection.

Abstract No. 134

Simple Method of Determining Crystal Perfection, II

H. K. Herglotz, Pigments Dept., E. I. du Pont de Nemours & Co., Inc., Newport, Del. (present address: Oesterreichische Stickstoffwerke, Linz/Donau, Austria)

Additional experimental results demonstrate the usefulness of the semi-quantitative scale for crystal perfection suggested in Part I of this paper. Quantitative investigations make use of the close resemblance of single crystal perfection and orientation in rolled sheets. These quantitative evaluations also show a method of increasing the reliability of the semi-quantitative scale by use of alloyed x-ray tube targets.

Abstract No. 135

Synthesis and Crystal Pulling of Gallium Arsenide in a Magnetic Crystal Puller

K. Weiser and **S. Blum,** International Business Machines Corp., Poughkeepsie, N. Y.

An all-quartz magnetic crystal puller is described in which GaAs is synthesized *in situ* and then pulled from the melt. Details of the puller are given, and the preparation of both doped and undoped material is described. Some electrical properties in the temperature range from 4° to 750°K of n- and p-type single crystals prepared in this manner are reported.

Abstract No. 136

Graded Energy Gap Alloy Semiconductor—$GaAs_xP_{1-x}$

R. E. Johnson and **George Towns,** Central Research Labs., Texas Instruments, Inc., Box 1079, Dallas, Texas

Alloy semiconductors have been prepared for possible use in thermoelectric devices. This study describes the preparation of a graded energy gap alloy semiconductor, $GaAs_xP_{1-x}$, where x varies with position along the bar. For use in high-temperature thermoelectric applications, it is possible to match the composition gradient of the alloy to the thermal gradient of the element for maximum efficiency. Evaluation results at various selenium doping levels are described.

Abstract No. 137

Preparation of Gallium Phosphide under Moderate Pressures of Phosphorus Vapor

J. F. Miller, R. C. Himes, and **H. L. Goering,** Battelle Memorial Institute, Columbus 1, Ohio

Results of experiments on the crystallization of GaP under moderate pressures of phosphorus vapor (1-5 atm) are presented. Sound transparent ingots of the compound have been prepared by the Bridgman method (2-5 atm) and by the Czochralski technique (1-3 atm). Apparatus and procedures used are described in some detail. Exploratory work on other "low-pressure" preparation methods and results of recent experiments are also discussed briefly.

Abstract No. 138

Direct Recombination in GaAs

S. Mayburg, Bayside Labs., General Telephone and Electronics Labs. Inc., Bayside, N. Y.

Experimental evidence for direct recombination in GaAs is obtained by showing a decrease in lifetime with injection level in contrast to indirect semiconductors like Ge where lifetime stays constant or increases with injection level. Stimulated emissions of electrons from the conduction to the valence band with photons of energy of the band gap have also been observed. Some consequences of direct recombination on GaAs device characteristics are discussed.

Abstract No. 139

Reactions between Gallium and Quartz

L. M. Foster and **R. A. Kramer,** Alcoa Research Labs., Aluminum Co. of America, New Kensington, Pa.

From simple thermodynamic considerations, gallium metal cannot react with silica. For the reaction $SiO_2 + Ga \rightarrow Si + Ga_2O_3$ the free energy change at 1273°K is +138 kcal. Because of the considerable solubility of silicon in gallium at high temperatures, however, this reaction can proceed until the silicon content reaches 1×10^{-7} atom % in the gallium. Vacuum heating experiments in all quartz environments have shown that attack on the quartz is much greater than this. The findings can be explained by the reaction $SiO_2 + Ga \rightarrow Si + Ga_2O$ and the volatilization of the gallium suboxide.

Abstract No. 140

Analysis of Impurities in Compound Semiconductors

G. D. Perkins, C. F. Robinson, and **R. K. Willardson,** Research Div., Consolidated Electrodynamics Corp., Pasadena, Calif.

Problems involved in the application of mass spectrometry to the detection and identification of impurities in compound semiconductors are discussed. A typical problem is the detection of silicon in InSb, AlSb, GaAs, or in fact any other matrix. At mass $28^{\pm 0.03}$ a quadruplet consisting of Si, Co, N_2, and C_2H_2 is usually found, and a resolution of at least 1:1600 is required. Mass spectrographic analyses are compared with impurity concentrations expected from controlled impurity additions and electrical analysis.

Abstract No. 141

Some Comments on the Electronic Structure of Group IV and III-V Semiconductors

S. L. Matlow, Hoffman Electronics Corp., El Monte, Calif.

The evidence for the structure of the valence band of the elements and intermetallics which crystallize in

the diamond-cubic, zinc blend, or wurtzite structures being the $\sigma(sp^3)$ band is so extensive that the model is almost universally accepted. Except for the C and BN systems it is not clear whether the conduction band is the $\sigma^*(sp^3)$ band or the $\pi(d)$ band. Chemical, crystallographic, spectroscopic, and electrical data are presented which indicate that $\pi(d)$ model is the more accurate.

Abstract No. 142

Physical Properties of p-Type Zn_3As_2 and n-Type Cd_3As_2

W. J. Turner, A. S. Fischler, and **W. E. Reese,** Research Lab., International Business Machines Corp., Poughkeepsie, N. Y.

Zn_3As_2 and Cd_3As_2 are II-V semiconductors which obey normal valence rules. Both compounds are tetragonal with solid-solid phase transitions at elevated temperatures. The single crystals reported on were prepared in this laboratory. In general, p-type Zn_3As_2 has a room-temperature hole mobility of less than 30 cm^2 v sec. From Hall data the carrier concentration in undoped material was approximately 5×10^{17} cm^{-3} in the range 77°-300°K. Selenium appears to act as a deep level compensator when added to the melt. The intrinsic optical gap of Zn_3As_2 at 300°K is 0.93 ev. Electron Hall mobilities as high as 15,000 cm^2/v sec have been observed in n-type Cd_3As_2 with net carrier concentration of 3×10^{18} cm^{-3}. The Hall coefficient remains constant from 4° to 300°K. The room-temperature optical gap obtained from absorption measurements is 0.13 ev.

Abstract No. 143

Mobility Doping of Semiconducting Compounds

A. J. Cornish, Solid State Physics Dept., Westinghouse Research Labs., Beulah Rd., Churchill Boro., Pittsburgh 35, Pa.

Doping of semiconducting compounds is normally accomplished by adjusting carrier densities. In many applications it appears advantageous to be able to control the mobilities of the carriers as well as the densities. Mobility doping, the adjustment of the mobilities of the carriers, is explained and illustrated.

Abstract No. 144

Thermoelectric and Crystallographic Properties of Ag_2Se

J. B. Conn and **R. C. Taylor,** Merck Sharp and Dohme Research Labs., Rahway, N. J.

Silver selenide has been prepared by fusion techniques and found to be an excellent thermoelectric material. The Seebeck coefficient, resistivity, and thermal conductivity have been measured as a func-

tion of temperature. The effect of doping with 30 different elements and compounds at different doping concentrations has been studied. The inter-relationships between the thermoelectric properties have been examined and are discussed. The crystal lattice of silver selenide has been determined, and the subcell and superstructure are elucidated.

Abstract No. 145

Properties of HgSe-HgTe Alloys

T. C. Harman, A. J. Strauss, and **L. B. Farrell,** Lincoln Lab., Massachusetts Institute of Technology, Lexington 73, Mass.

The phase diagram for the pseudo-binary system HgSe-HgTe has been determined by differential thermal analysis and x-ray diffraction techniques. Melting points measured for HgSe and HgTe are 799° and 670°C, respectively. Continuous solid solution occurs over the whole range of composition. Large single crystals of the alloys have been prepared by the Bridgman method, and data are presented on the electrical properties of the alloys as a function of composition, impurity concentration, and temperature.

Abstract No. 146

Crystal Orientation Effects Observed in Tin-Telluride Thin Films

S. H. Shortes and **D. P. Miller,** Texas Instruments Inc., P. O. Box 312, Dallas, Texas

Tin-telluride thin films may be oriented crystallographically to certain preferred directions either during evaporation or during subsequent annealment. Degree of orientation has been studied for different evaporation pressures and for effects of annealment ambient. X-ray diffraction measurements reveal either 111 or 110 crystal planes may be preferentially aligned parallel to the evaporation substrate. The results indicate that variations from stoichiometry of the film is sufficient for orientation. A tin-rich film orients to the 111 direction while a tellurium-rich film orients to the 110 direction.

Abstract No. 147

The Growth of Single Crystal Iron Ferrites by the Czochralski Method

F. H. Horn, Research Lab., General Electric Co., Schenectady, N. Y.

A procedure is described for growing iron ferrites into single crystals by pulling from the melt. An iridium crucible is used which, unlike platinum or platinum-rhodium alloys, does not react with ferrites. The melting and growing is performed in a carbon dioxide atmosphere. Problems attending this method of growth, such as the maintaining of stoichiometry and purity, are discussed.

Abstract No. 148

Titanium Thin Film Resistance for Microsystems Electronics

R. A. Quinn, Lockheed Missiles and Space Div., Lockheed Aircraft Corp., Palo Alto, Calif.

The material requirements of the MSE Program at LMSD have resulted in the development of chemical processes for the fabrication of a stable thin film resistance material. Titanium is deposited on a ceramic substrate using a fused-salt technique and then electrochemically processed to produce a thin film with stable resistance values up to 2000 ohms per square and useful from —65° to 250°C. The resistance is monitored during the conversion process so that exact values may be made. The dependency of resistance characteristics on the process control parameters is discussed.

Abstract No. 149

Some Statistics of Doping Silicon Crystals

J. W. Brownson and **R. Saphir,** Semiconductor Div., Raytheon Manufacturing Co., 150 California St., Newton 58, Mass.

The application of statistical techniques to crystal doping problems has yielded several valuable process techniques as well as improved understanding of impurity variations in silicon material. Some of the techniques which have been evolved are evaluation of raw silicon, optimization of doping, doping process control, analysis of scrap and its recovery, and the detection of unsuspected contaminants in the material. Those new techniques have quantified analytically the variations of impurity levels within and among samples of the various forms of silicon. The causes of these variations have been analyzed partially.

Abstract No. 150

Method of Evaluating Silicon Monocrystals for the Fabrication of Diffused Junction Devices

A. Ertel, ITT Components Div., International Telephone and Telegraph Corp., Clifton, N. J.

During the manufacture of silicon diffused junction devices, such as rectifiers and zener voltage regulators, changes in resistivity during high-temperature diffusion operations along with initial crystal imperfections may result in devices having reverse voltage characteristics other than those desired. A method of predetermining the quality of devices which may be expected from a given monocrystal is described. Characterization is made immediately after diffusion and prior to device fabrication. Some typical evaluations are described and discussed in detail.

Abstract No. 151

A Modified Closed Box System for the Diffusion of Boron in Silicon

R. S. Yatsko and **J. S. Kesperis,** U. S. Army Signal Research and Development Lab., Fort Monmouth, N. J.

A modified closed box diffusion system has been investigated over a wide range of conditions. Boron layers have been diffused in silicon from B_2O_3-SiO_2 sources ranging from concentrations of 0.2% B by weight to pure B_2O_3. Nonmelting source conditions have been varied to melting source conditions yielding surface concentrations ranging from 10^{18} to 10^{21} carriers/cc. Some effects of environmental atmospheres and materials are discussed. Applications to photovoltaic devices and double diffused transistors are described.

Abstract No. 152

Some Effects of Paint Strength Variation in Paint-on Diffusion of Silicon

J. E. Reynolds and **W. Gegg,** Semiconductor Products Div., Motorola Inc., 5005 E. McDowell Rd., Phoenix, Ariz.

Control of impurity diffusion of phosphorus and boron into silicon by the paint-on procedure has been investigated. Concentrations of P_2O_5 and B_2O_3 were varied over a range of 16-fold in di-methoxyethanol as the solvent. Evaluation of surface concentration, sheet resistance, and electrical parameters of assembled devices were made involving double anode diffusions of N- and P-type silicon for resistivities ranging from 0.001 to 15 ohm-cm. Several different diffusion atmospheres involving N_2, O_2, and H_2O were used. Results are given, and it is concluded that paint composition can be used for limited control of surface concentration and hence electrical parameters.

Abstract No. 153

Etching Ge with "Superoxol"

J. Bloem and **J. C. van Vessem,** Semiconductor Development Lab., N. V. Philips' Gloeilampenfabrieken, Nijmegen, Netherlands

Hf—H_2O_2—H_2O is a widely used etchant for germanium single crystals. A survey is given of the influence of etch rate on the composition of the etchant and surface structures after etching (which may be important in device fabrication) are studied. A quantitative description of the experimental results is presented whereupon correlations and differences between etching and alloying can be explained.

Abstract No. 154

Dissolution of Germanium in Hydrogen Peroxide

Pei Wang and **Nino Cerniglia,** Semiconductor Div., Sylvania Electric Products Inc., Woburn, Mass.

The dissolution rate of germanium in aqueous hydrogen peroxide solution has been studied in relation to hydrogen peroxide concentration, *p*H, and temperature of the solution. The dissolution rate has been found independent of the hydrogen peroxide concentration, etching time, and *p*H of the solution over a wide range. It is strongly *p*H dependent above *p*H 5.5 at the temperature investigated (25°-70°). The reaction mechanism, which seems to have a *p*H dependence, is discussed.

Abstract No. 155

Sizing of Semiconductor Dice by Controlled Chemical Etching

R. B. Soper, Sylvania Electric Products Inc., Woburn, Mass.

A controlled chemical etching process by which semiconductor dice may be reduced uniformly in thickness is described. The process is particularly effective because uniformity of temperature, concentration of the etchant, and interfacial relationship are maintained. Etching so controlled yields high-quality dice of predictable thickness. An etching apparatus satisfying these conditions and capable of etching production quantities of germanium dice also is discussed.

Abstract No. 156

A New Technique for the Preparation of Flat Germanium Surfaces

M. V. Sullivan and **R. M. Finne**, Bell Telephone Labs., Inc., Murray Hill, N. J.

A new electropolishing technique has been developed which employs the gentle stirring of the electrolyte near the germanium surface being electropolished. With a "flat" stirring surface, etching on the high points is accelerated, and the germanium can be electropolished to a scratch-free mirror finish at rates of 0.02-2 mm/hr. Germanium polished in this manner has a surface roughness of less than 5×10^{-7} cm and an over all flatness of 2×10^{-4} cm over a 1 in.^{2} area.

Abstract No. 157

The Wetting of Germanium by Molten Indium

A. A. Bergh and **L. H. Holschwandner,** Bell Telephone Labs., Inc., Allentown, Pa.

Different types of unwetted areas on germanium-indium alloy junction transistors are revealed by

methods of etching and sectioning for microscopic examination. Among the factors influencing wetting, the roles of indium and germanium oxides and of occluded gases are discussed. The mechanism of the formation of the different unwetted areas and ways to achieve good wetting are shown. Finally, some correlation is presented between wetting and electrical characteristics.

Abstract No. 158

Nuclear Magnetic Resonance of Water Adsorbed on Silicon

C. G. McCormick and **G. K. Walters,** Central Research Labs, Texas Instruments Inc., P. O. Box 1079, Dallas, Texas

Using the spin-echo technique, preliminary measurements have been made of the spin-lattice and spin-spin relaxation times, T_1 and T_2, of protons in water adsorbed on finely powdered silicon. For coverages up to five monolayers the values of T_1 and T_2 are found to be considerably shorter than those reported for water adsorbed on silica gel and titanium dioxide. A time dependent increase in T_2 is observed for a coverage of approximately one monolayer.

Abstract No. 159

The Retention of Water by the Real Silicon Surface

S. S. Baird, Central Research Labs., Texas Instruments Inc., P. O. Box 1079, Dallas, Texas

Crushed, low resistivity, n-type silicon was treated with various reagents, washed, and dried by several techniques. The water remaining on the surface after drying was determined titrimetrically with Karl Fisher reagent. Results are presented for surfaces prepared by treatment with various reagents commonly used in the manufacture of silicon devices, and a model of the real silicon surface is proposed to explain the observed results.

Abstract No. 160

D-C Field and Noise Measurements on Silicon

B. R. Pagel, Central Research Labs., Texas Instruments Inc., P. O. Box 1079, Dallas, Texas

D-C field and noise measurements have been made on single-type crystals of silicon. The material was high resistivity p-type, with two types of surfaces: a hydrophobic surface, freshly etched, and a hydrophilic surface, prepared by soaking in HF. The surface potential was changed with the d-c field in the presence of several ambient gases and vacuum. The results of this experiment are reported showing the variation of the excess noise generated in connection to the surface as the surface states and surface potential are changed.

Abstract No. 161

Variation with Frequency of the Transverse Impedance of Semiconductor Surfaces

F. Berz, Mullard Research Labs., Cross Oak Lane, Salfords, nr. Redhill, Surrey, England

A theoretical investigation is carried out on the variation with frequency of the transverse impedance of surface layers in semiconductors. This variation shows two main relaxation times corresponding to the filament lifetime and to the relaxation time of the fast states. Numerical examples illustrate the results. Some factors affecting the validity of the linear treatment are discussed briefly.

Abstract No. 162

Differential Capacity and Surface Conductivity of the Silicon Electrolyte Phase Boundary

R. M. Hurd and **P. T. Wrotenbery,** Texas Research Associates, 1701 Guadalupe St., Austin 1, Texas, and **Don Arnold,** Texas Instruments Inc., P. O. Box 312, Dallas, Texas

Results of measurements of the differential capacity and surface conductivity of silicon surfaces in contact with both acidic and basic electrolytes have been compared to values calculated from space charge theory. Deviations between theory and experiment have been used to draw some tentative conclusions as to the distribution of the potential drop across the space charge and through the phase boundary, and to the nature of possible surface states.

Abstract No. 163

Characteristics of the {111} Surfaces of the III-V Intermetallic Compounds, II. Effect of Surface Active Agents

M. C. Lavine, M. C. Finn, and **H. C. Gatos,** Lincoln Lab., Massachusetts Institute of Technology, Lexington 73, Mass.

Certain surface active agents (organic or inorganic) act preferentially on either the {111} surfaces terminating with group III atoms or the {111} surfaces terminating with group V atoms. The preferential action is reflected not only in the appreciable decrease of the dissolution rates of these surfaces but also in the size and geometric shape of the resulting etch figures and dislocation pits. The role of the surface active agents in the dissolution and etching behavior of the III-V intermetallic compounds is interpreted on the basis of specific adsorption and the resulting changes in the rate components parallel and vertical to the surface.

Abstract No. 164

High-Temperature Oxidation Studies on the (111) and the (111) Surfaces of InSb and GaAs

T. R. Perry, J. G. Harper, and **D. P. Miller,** Texas Instruments Inc., P. O. Box 312, Dallas, Texas

Gatos and Lavine have indicated the effect of polarity on the (111) surfaces in the etching behavior of III-V compounds. This phenomenon has been measured semi-quantitatively in InSb and GaAs. Oxidation reactions are performed in oxygen and in air and the relative reaction rates are measured by differential thermal analysis (DTA). The data indicate qualitative agreement with Gatos and Lavine. The A faces begin to oxidize at a lower temperature, but the oxidation of the B faces soon becomes the predominate one and proceeds at a much faster rate.

Abstract No. 165

Properties and Reactions of Stain Films on Silicon

Allen Gee, Semiconductor-Components Div., Texas Instruments Inc., P. O. Box 312, Dallas, Texas

Silicon when etched with certain mixtures of nitric and hydrofluoric acids is frequently stained. Such stains, consisting essentially of amorphous silicon, have been avoided in fabrication of semiconductor devices. When subjected to controlled chemical or anodic oxidation, these stain films manifest some interesting properties. Electrode potential, electrical characteristics, and luminescence associated with film-covered silicon are discussed.

Abstract No. 166

The Study of Surface Contamination of Semiconductors by Radiochemical Techniques

G. B. Larrabee, Central Research Labs., Texas Instruments Inc., P. O. Box 1079, Dallas Texas

This paper describes a recent study of the adsorption of metallic ion impurities from solution by intermetallic semiconductors. A mechanism for this adsorption is presented and an attempt is made to correlate this mechanism with silicon surface adsorption studies.

Abstract No. 167

Encapsulation of Silicon Diodes in Low Melting Glass, I. Materials and Processes

I. L. Kalnin and **A. P. Pisarchik,** Bell Telephone Labs., Inc., Murray Hill, N. J.

The dip encapsulation of diffused silicon diodes in low melting, that is below 350°C, arsenic-sulfur-thallium and arsenic-sulfur-iodine glasses is described. Glass properties, processing techniques, and encapsulation results are discussed. Limitations of this type of encapsulation depend on the flow temperature of the glass and the difference in the thermal expansivities of the materials involved. The useful temperature range of the encapsulated diodes in the particular glasses used is approximately −40° to +100°C. Glass dip encapsulation is shown to improve diode characteristics.

Abstract No. 168

Encapsulation of Silicon Diodes in Low Melting Glasses, II. Electrical Characteristics

W. F. J. Hare, Bell Telephone Labs., Inc., Murray Hill, N. J.

The initial values and the stability of the electrical characteristics of silicon diodes encapsulated in low melting arsenic-thallium-sulfur glasses has been investigated. Three hundred diodes have been monitored while under forward or reverse bias, at various temperatures, for 3000 hr. The reverse current of diodes drifts consistently upward when aged under reverse bias and downward when aged under forward bias, reaching an equilibrium in about 1000 hr. Both the initial reverse currents and these equilibria are at low values, of the order of 10^{-9} amp, as compared with values of 10^{-8} for conventional production devices. These aging characteristics are adequately explained by an ion-migration model.

ELECTROTHERMICS AND METALLURGY

Abstract No. 169

Vacuum-Evaporated Titanium Coatings

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Thick titanium films have been successfully vacuum evaporated on low alloy steels as corrosion resistant coatings. Typical metallized films when properly treated exhibit excellent corrosion resistant properties. Coating thicknesses in the range 0.02-1.2 mils can be achieved by means of multiple boat evaporations. Excellent coating adhesion is accomplished by means of a vacuum diffusion technique, and basis metal degassing. A photomicrographic and x-ray diffraction study of laboratory produced coatings provides supplementary information on the metallurgical and crystallographic nature of the thick evaporated titanium coatings.

Abstract No. 170

Deposition of InSb Films by Flash Evaporation

E. H. Layer, F. J. Reid, and **A. E. Austin,** Battelle Memorial Institute, Columbus 1, Ohio

A method of preparing films of InSb is described. It depends on the evaporation and condensation of indium and antimony in equal proportions by the creation of "instantaneous" evaporation conditions. These conditions were created by feeding granular InSb onto a preheated evaporation strip in vacuum. X-ray diffraction, resistivity, and Hall coefficient data show that (*a*) major phase was InSb, (*b*) crystallite sizes ranged up to approximately several thousand angstroms, and (*c*) crystallites were less pure than the single crystal material which was granulated for the evaporant.

Abstract No. 171

Vacuum Sintering of Tungsten Ingots

J. W. Pugh and **L. H. Amra,** Refractory Metals Lab., General Electric Co., Cleveland, Ohio

A furnace for vacuum sintering tungsten is described and results obtained from tungsten sintering experiments are discussed. The rate of densification at various temperatures is given special emphasis, but microstructure, hardness, fabricability and purity are also examined. Temperatures from 1800° to 3100°C and times from 0.25 to 8.00 hours were employed. Results indicate that sintered densities at least as high as 82.5% of theoretical density are necessary for successful fabrication, and that densities as high as 97.0 have structures which are readily fabricable. High temperature vacuum sintering is found to produce very pure tungsten, commensurate in this respect with the best arc cast tungsten.

Abstract No. 172

Reactions in the Niobium-Nitrogen System

W. M. Albrecht (present address: Glendale Lab., International Business Machines, Endicott, N. Y.) and **W. D. Goode,** (present address: Gaseous Diffusion Plant, Union Carbide Nuclear Co., Oak Ridge, Tenn.) Battelle Memorial Institute, Columbus 1, Ohio

The rates of the reactions of nitrogen with niobium were studied at 200°-1600°C. The reaction was found to follow a logarithmic rate law below 600°C. Above this temperature, the reaction followed a parabolic rate law with a change in mechanism between 975° and 1100°C. The diffusion coefficients and terminal solubilities of nitrogen in niobium were determined at 800°-1600°C.

Abstract No. 173

Preparation of Rare Earth Master Alloys

S. J. Morana, The Beryllium Corp., Hazleton, Pa.

A new and improved method of preparing rare earth master alloys directly from the rare earth halide salt results in the production of a rare earth master alloy comprised of the rare earth metal, the base metal, and a small percentage of magnesium. Base metal produced has included nickel, aluminum, manganese-aluminum, titanium-aluminum, copper, etc., containing 10-30% rare earth metal. Base metal selected is dependent on metal to be treated with rare earth.

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